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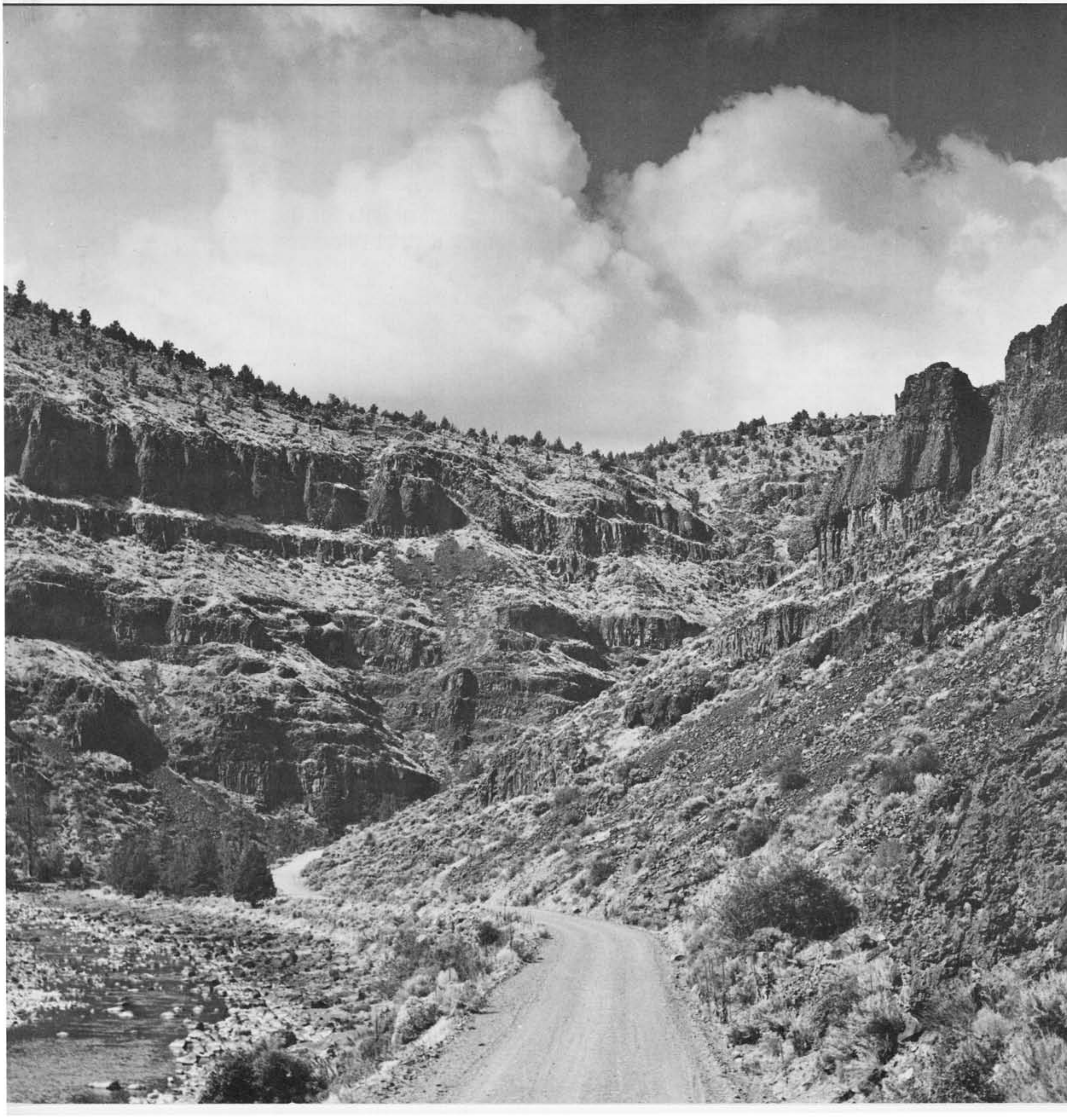

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COVER PHOTO

Crooked River canyon, east of Prineville, Oregon. Article beginning on p. 8 discusses thermal springs occurring near the confluence of the Crooked, Metolius, and Deschutes Rivers to the west of this area and west of Madras, Oregon. Photo courtesy of Oregon State Highway Commission.

Haagensen appointed to DOGAMI Governing Board; Rasmussen elected Chairman

Donald A. Haagensen, Portland, has been appointed by Governor Vic Atiyeh to the three-member Governing Board of the Oregon Department of Geology and Mineral Industries. He succeeds John Schwabe of Portland, whose term expired this fall. Schwabe served on the Board since September 19, 1977, and was the Board's Chairman since 1979.

Haagensen, an attorney with the Portland law firm of Schwabe, Williamson, Wyatt, Moore, and Roberts since 1977, received his bachelor of science degree from The College of Idaho, Caldwell (1967), and masters of science (1974) and law (1977) degrees from the University of Miami, Coral Gables, Florida.

At its December 8, 1981, meeting in Portland, the Board elected C. Stanley Rasmussen of Baker as its new Chairman. Rasmussen, who is Vice President and Oregon Electric Division Manager of CP National, has been a member of the Governing Board since fall of 1979. □

Geochemical data for Quartzville mining district released

Geochemical data for the Quartzville mining district in Linn County are available now in an open-file report recently released from the Oregon Department of Geology and Mineral Industries (DOGAMI). The Department has placed on open file Report 0-81-8, *Reconnaissance Geochemical Study of the Quartzville Mining District, Linn County, Oregon*, by Steven R. Munts.

The 14-page report includes tabulated results of analyses for lead, zinc, and copper for 27 samples of altered volcanic host rocks, 47 samples of granitic intrusive rocks, and 134 soil and sediment samples. The rock samples were also analyzed for molybdenum and silver. A sample location map (scale 1:12,000) is keyed to the sample numbers in the tables.

The Quartzville mining district is one of Oregon's well-known, older mining areas. Organized in 1864 and operated mostly in the 1860's and 1890's, it has been the object of intensive geologic investigation in recent years.

DOGAMI Open-File Report 0-81-8 is now available at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $4.00. Orders under $20.00 require prepayment. □

Meteorite information requested

A fireball was sighted Thursday night, December 3, 1981, between 10:20 and 10:25 p.m. in the Estacada-Molalla area near Portland. Anyone with information about the event or the meteorite that caused it is asked to contact Dick Pugh, Cleveland High School. His phone number during the day is (503) 233-6441. □

CONTENTS

Problems in the regional stratigraphy of the Strawberry Volcanics

by Greg Wheeler, Department of Geology, California State University at Sacramento, Sacramento, Calif. 95819

ABSTRACT

Some portions of the Strawberry Volcanics of northeastern Oregon have lost petrographic and stratigraphic identity because intrusive and volcanic rocks that are not stratigraphic correlatives with the Strawberry Volcanics in the type locality have been included in the unit.

Flow units of the Strawberry Volcanics along the Middle Fork of the John Day River near Bates, Oregon, are basalt and andesitic basalt. These rocks are columnar jointed and have platy jointing perpendicular to the flow surface. A potassium-argon age of 9.96 ± 0.24 m.y. (million years) and leaf fossils found in intercalated diatomite pods support a middle to late Miocene age for these rocks. Elsewhere, other rocks of the volcanic series have been dated at between 10 and 20 m.y.

Although many intrusive rocks in the Strawberry Volcanics outcrop area have previously gone unnoticed, they can be distinguished from stratigraphically significant flow rock by their metamorphosed and iron-stained contact zones; concentric, concave-outward joint patterns; and absence of some flow structures. A 40.06 ± 1.06-m.y. age for the intrusive plug at Cow Camp, just east of Bates, Oregon, confirms the Eocene age of this intrusion. The Cow Camp plug is representative of many other intrusions which have been mapped as Strawberry Volcanics but which are actually equivalent in age to the Clarno Formation. Age determinants in other intrusions give an Oligocene age contemporaneous with John Day Formation volcanism. Some intrusions may be nearly contemporaneous with the flows of the Strawberry Volcanics which they intrude.

INTRODUCTION

Much of the 161,000 km² (62,100 mi²) of eastern Oregon is covered by Tertiary-age volcanic rock. Rocks mapped as Strawberry Volcanics cover approximately 2,500 km² (975 mi²), mostly in eastern Grant and western Baker Counties (Brown and Thayer, 1966; Robyn, 1977; Walker, 1977). The Canyon City 1° × 2° quadrangle contains 80 percent of the mapped outcrops of the formation (Figure 1).

The rocks were first described by Thayer (1957) (Figures 1 and 2) at the type area at Strawberry Mountain, which is 27 km (17 mi) southeast of John Day, Oregon. The principal sources of the Strawberry Volcanics are two eruptive vent complexes in Unity Basin east of the type locality (Robyn, 1977, p. 144). The formation was originally described as "pale-gray, fresh basaltic to andesitic hypersthene-bearing lavas," with minor amounts of more silicic volcanic rock (Thayer, 1957, p. 237). Brown and Thayer (1966) included olivine basalt, dacite, and rhyolite in their descriptions of rocks mapped as Strawberry Volcanics in the Canyon City quadrangle. Thayer and Brown (1973, p. 492) described a 2,100-m (6,900-ft)-thick section of Strawberry Volcanics which is half rhyolite and half andesite in the Ironside Mountain quadrangle. Robyn (1978, p. 144) states that the Strawberry Volcanics are characteristically calc-alkaline andesites, but their composition ranges from high-alumina basalts to dacite. Thus the original petrographic description has been expanded to include many varieties of volcanic rock.

Thayer (1957, p. 239) considered the Strawberry Volcanics equivalent to the upper Miocene Columbia River Basalt of northeastern Oregon. Potassium-argon ages on rocks mapped as Strawberry Volcanics (reported in Wheeler, 1976, p. 68) within the Canyon City 1° × 2° quadrangle (Brown and Thayer, 1966) range from late Miocene to Eocene. Robyn (1977) has proved that the majority of the Strawberry Volcanics were deposited between 15 and 20 m.y. ago but that volcanism began 20 m.y. ago and continued episodically until at least 10 m.y. ago.

This study was undertaken to help clarify the stratigraphic significance and petrographic identity of the Strawberry Volcanics. Three weeks were spent in reconnaissance mapping of the Strawberry Volcanics in the Canyon City 1° × 2° quadrangle. Two more weeks were spent in detailed mapping and study of the northwestern outcrops of Strawberry Volcanics in the Bates 15-minute quadrangle, a part of the Canyon City 1° × 2° quadrangle. The detailed study was a small part of a doctoral dissertation (Wheeler, 1976).

GENERAL CHARACTER

Strawberry Volcanics rocks in the Bates quadrangle are gray, with light-green mottling and thin, pinkish veins of

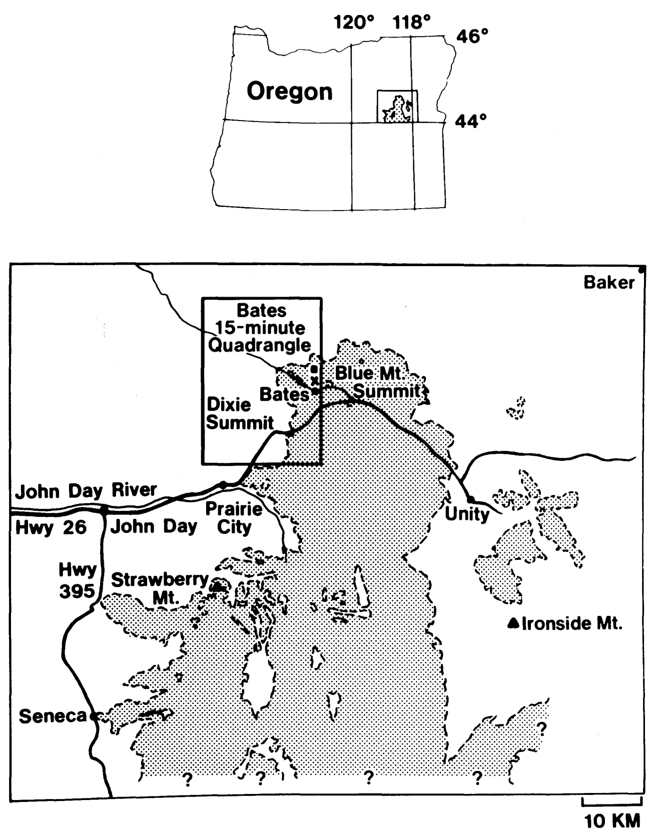

Figure 1. Map showing the extent of rock units included in the Strawberry Volcanics (stippled pattern). Solid black block marks Vinegar Hill, the collection locality of fossils listed in Table 1. X marks the collection locality of basaltic andesite dated 9.96 ± 0.24 m.y. using potassium-argon whole rock analysis.

Figure 2. Basaltic to andesitic hypersthene-bearing lavas in the Strawberry Volcanics type section immediately west of Strawberry Lake on Strawberry Mountain.

altered iron minerals. Microscopic studies indicate the rock is 85 percent zoned plagioclase with An_{35} rims and An_{45} cores. Cumulophyric clots of plagioclase and augite are common. No olivine and only a trace of hypersthene were found. The lack of vesicles in most rock samples in this area indicates low gas content. This mineralogy is distinct from the hypersthene-rich basaltic andesites originally described by Thayer (1957, p. 237) as characteristic of the type Strawberry Volcanics.

Most of the basaltic andesite that crops out northwest of Bates, Oregon, has columnar jointing; in some areas, such as the east summit areas of two hills* in the east-central portion of the Bates 15-minute quadrangle, columns have fallen intact to form large "post-pile" deposits. Whether or not the columnar jointing is apparent, platy jointing perpendicular to flow surfaces is pervasive. Weathering of these resistant outcrops produces large quantities of rubble which cover the gentle slopes (Figure 3). The platy jointing found near Bates is not present in many of the outcrops studied further south. Individual flows of basaltic rock are much more distinct near Strawberry Lake than further to the north.

Leaf-bearing diatomite and diatomaceous tuffs occur interbedded with the columnar-jointed volcanic rocks on lower Vinegar Creek in the Bates 15-minute quadrangle and elsewhere in the northern part of the area mapped as Strawberry Volcanics. The Slide Creek flows at Vinegar Creek are considered by Robyn (1977, p. 17, 31) to be basal flows of the Strawberry Volcanics.

The dips of the beds are always gentle. Beds dip 13° to the southwest and strike northwesterly at Vinegar Creek. Similar low dips were measured on Strawberry Mountain. The aggregate thickness of flows appears to be less than 170 m (560 ft) near Bates, but the unit becomes thicker toward Strawberry Mountain. A 2,100-m (6,900-ft) section has been described in the Ironside Mountain 30-minute quadrangle (Thayer and Brown, 1973, p. 492).

* One hill in sec. 5, T. 10 S., R. 35 E., can be identified on a topographic map by its elevation of 5,492 ft, the other hill in sec. 8, T. 10 S., R. 35 E., by an elevation of 4,765 ft.

CORRELATION AND AGE

The Strawberry Volcanics are unconformable over all older rocks of the region. Volcanic mudflows of the Clarno Formation underlie the Strawberry Volcanics along the northern and eastern edges of the area mapped. The Clarno Formation dips 10° to 20° more steeply than the Strawberry Volcanics. The contact between the two units is marked in many places by a soil horizon, baked zone, and considerable topographic relief along the old erosion surface. Steeply dipping pre-Tertiary rocks directly underlie the Strawberry Volcanics at some localities.

Brown and Thayer (1966) considered the Strawberry Volcanics equivalent to the Columbia River Group. The group is separated by a marked unconformity from the overlying Rattlesnake Formation of middle Pliocene and Pleistocene(?) age (Shotwell, 1956, p. 719) and includes the Mascall Formation. Brown and Thayer (1966) believed the Columbia River Group interfingers with the Strawberry Volcanics in the John Day River valley. The basalt flows of the Columbia River Group have recently been separated from the sedimentary units and are now called the Columbia River Basalt Group (Griggs, 1976, p. 6; Swanson and others, 1979, p. 15). Brown and Thayer (1966) stated that flows belonging to the Strawberry Volcanics interfinger with the early Pliocene lacustrine deposits in the Unity Basin (Shotwell, 1956). This interfingering relationship has been confirmed in remapping of the area by Robyn (1977, p. 7).

Figure 3. Rubble along Vinegar Creek 1.5 km (1 mi) east of Bates, Oregon. The Strawberry Volcanics exhibit columnar joints truncated by platy jointing.

Thayer's conclusion that the Strawberry Volcanics were contemporaneous with the Columbia River basalt lavas was partially based on evidence obtained from exposures in cirques along the north side of Strawberry Mountain. There, according to Thayer, "basalts indistinguishable from known Columbia River basalt between Mt. Vernon and Picture Gorge" are intercalated with lower flows of the Strawberry Volcanics (Thayer, 1957, p. 237). However, the basalt flows at Strawberry Mountain are not continuous with Columbia River basalt units and are equally well interpreted as basaltic members of the Strawberry Volcanics. Thayer and Brown (1973, p. 492) describe basalt units such as these in Strawberry Volcanics along King and East Camp Creeks in the Ironside 30-minute quadrangle. Many such basalt flows are described by Robyn (1977).

The Strawberry Volcanics are not in contact with the Columbia River Basalt Group in the Bates quadrangle nor do they contact proved Columbia River Basalt Group or Mascall Formation rocks at any known outcrop (Brown and Thayer, 1966; Robyn, 1977; and personal field investigations).

Pods of intermixed diatomite and tuff between flows in the northwestern part of the mapped area probably formed in small ponds on the old flow surfaces. Many of these pods contain a wide variety and large quantities of leaf and seed fossils. Fossil plants collected 60 m (200 ft) stratigraphically below flows dated as 9.96 m.y. old (Wheeler, 1976, p. 68) from the NW¼ sec. 16, T. 11 S., R. 35 E., in the Bates quadrangle (Figure 1), were submitted to Charles Smiley of the University of Idaho. Smiley identified 21 plant species (Table 1) "of Miocene age but probably not as old as the Mascall." The flora "could well be as young as the lower Ellensburg (probably about 12 m.y.) or the upper Miocene Hog Creek of Idaho" (1977, written communication). Chaney (1959, p. 61) describes this fossil locality and others just to the east. He states that there is "no reason to question the conclusion that the leaf-bearing strata and the basalts below and above them were laid down with no perceptible break in time" (p. 62). Field observations of this author concur with those of Chaney. The fossil evidence yields an age significantly younger than the 15-m.y. age suggested by Robyn (1977, p. 17, 31) for these rocks.

Rocks mapped as Strawberry Volcanics have yielded a wide range of potassium-argon ages. Walker and others (1974) report an age of 12.2 ± 0.4 m.y. for a rhyolite which is 17 km (10 mi) southeast of Seneca and which has been mapped as Strawberry Volcanics. J.F. Sutter dates a "massive andesitic lava" near the summit of Strawberry Mountain as 14.2 m.y. old (A.R. McBirney, 1974, written communication). In contrast to these Miocene ages are the ages of 24.3 m.y. for an "andesitic lava 3.2 km (2 mi) south of the north boundary of Malheur National Forest on the main road south of Prairie City" and of 29.4 m.y. for a "basaltic andesite 3.5 km (2.2 mi) east of the road to High Lake on the road to Seneca" (McBirney, 1974, written communication). On the basis of potassium-argon whole rock analysis, Sutter dates a basaltic andesite sample collected by the author from near the base of the Strawberry Volcanics section at the Bates airstrip as 9.96 ± 0.24 m.y. old (Figure 1).

Table 1. *Strawberry Formation flora species list. Collected by G.R. Wheeler in Bates quadrangle, Oregon, NW¼ sec. 16, T. 11 S., R. 35 E. Species identifications by C.J. Smiley, University of Idaho, December 1972*

Conifers:
- *Picea lahontense* MacGinitie
- *Pinus tiptoniana* Chaney and Axelrod
- *Pseudotsuga* (or *Tsuga*) *sonomensis* Axelrod
- *Sequoia affinis* Lesquereux
- *Thuja dimorpha* (Oliver) Chaney and Axelrod

Dicots:
- *Acer bendirei* Lesquereux
- *Betula fairii* Knowlton
- *Castanea spokanensis* (Knowlton) Chaney and Axelrod
- *Cercidiphyllum crenatum* (Unger) Brown
- *Fagus* cf *idahoensis* Chaney and Axelrod
- *Fagus washoensis* LaMotte
- *Ostrya oregoniana* Chaney
- *Persea pseudocarolinensis* Lesquereux
- *Populus lindgreni* Knowlton
- *Populus voyana* Chaney and Axelrod
- *Quercus dayana* Knowlton
- *Quercus eoprinus* Smith
- *Quercus simulata* Knowlton
- *Salix knowltoni* Berry
- *Sassafras* cf *columbiana* Chaney and Axelrod
- *Zelkova oregoniana* (Knowlton) Brown

INTRUSIVE ROCKS

Failure to distinguish extrusive from intrusive rocks explains, in part, the wide range of potassium-argon ages attributed to the Strawberry Volcanics. Some intrusive rock units included with the Strawberry Volcanics may be nearly contemporaneous with the flow units. However, the Oligocene ages of

Figure 4. An andesite plug in the Clarno Formation along Camp Creek, sec. 25, T. 10 S., R. 32 E.

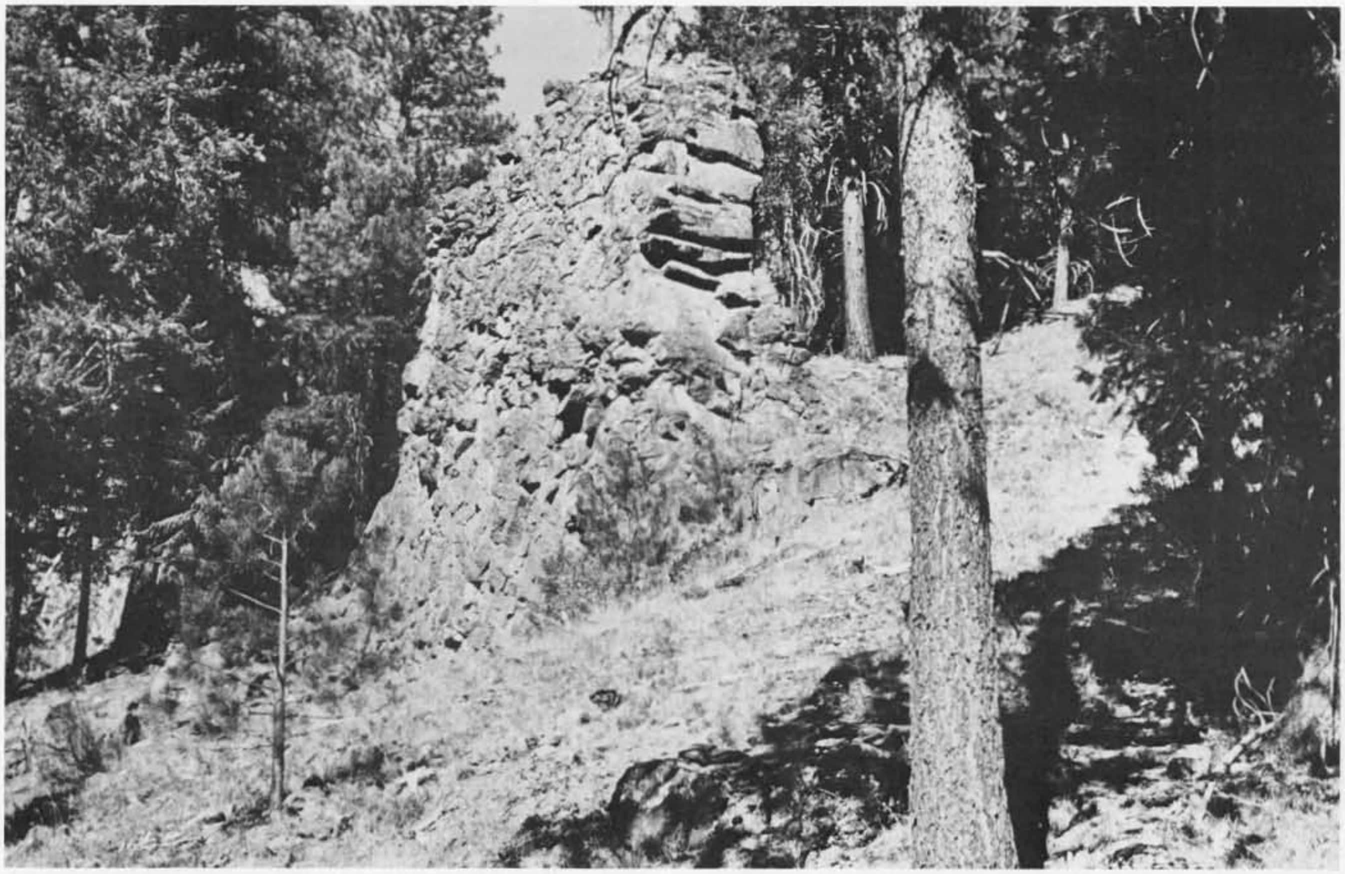

Figure 5. Hornblende andesite dike in the Clarno Formation northwest of Bates, Oregon, along the Middle Fork Road, sec. 5, T. 11 S., R. 34 E.

the above-mentioned two samples reported by McBirney must belong to rocks of an earlier, pre-Strawberry episode of igneous activity. These older rocks of roughly John Day age may be equivalent to small intrusions along U.S. Highway 26 near Dixie Summit and to many undated intrusions into the Clarno Formation of the Mitchell quadrangle to the west.

The large outcrop at Blue Mountain Summit on U.S. Highway 26 and the 0.1-ha (0.25-acre) outcrop at Cow Camp, east of Bates, are definitely intrusive. The steeply dipping contact with Eocene Clarno Formation conglomerate is brecciated, baked, and iron stained. The andesite at both locations has concentric, concave-outward joints such as those typically developed in a dome. The joints are closely spaced (10-20 cm [4-8 in]) and parallel to formational contacts. There are no flow structures and no columnar joints in these outcrops. Rocks collected by the author from the Cow Camp plug were dated by Sutter (1975, written communication) with potassium-argon methods. The resulting age of 40.06 ± 1.06 m.y. is well within the Clarno age group. There are many intrusives in the Clarno Formation (Figures 4, 5, and 6). This author believes that many intrusives of Clarno age have been mapped as Strawberry Volcanics, as was the Cow Camp plug.

CONCLUSIONS

Robyn's (1977) conclusion that the Strawberry Volcanics represent episodic eruptions beginning 20 m.y. ago and extending to the late Miocene is well supported. Although age determinants indicate contemporaneity of the Columbia River Basalt Group (Swanson and others, 1979) and the Strawberry Volcanics, no contacts between these units have been identified. Fossil evidence from the Bates quadrangle, potassium-argon ages from rocks at the Bates airstrip and the type locality, and field relationships indicate that the age of the Strawberry Volcanics is middle to late Miocene in much of the Canyon City $1° \times 2°$ quadrangle. This portion of the Strawberry Volcanics postdates Columbia River Basalt Group flows in that area. The petrographic variety in this post-Columbia River Basalt Group portion of the Strawberry Volcanics is not great. The majority of rocks are andesites and basaltic andesites.

Some intrusive units previously included in the Strawberry Volcanics are parts of earlier igneous sequences and should be recognized and excluded from this formation.

ACKNOWLEDGMENTS

Thanks are due to C.J. Smiley of the University of Idaho who identified fossil leaves and to J.F. Sutter who supplied

Figure 6. Sill in the Clarno Formation, near Sunshine Guard Station, sec. 26, T. 10 S., R. 33 E.

two critical radiometric dates through A.R. McBirney of the University of Oregon. Early stages of the research and writing were greatly aided through discussions with H.A. Coombs, E.S. Cheney, E.B. McKee, and H.E. Wheeler of the University of Washington and with T.P. Thayer of the U.S. Geological Survey. C.C. Plummer and N.C. Janke of California State University, Sacramento, critically reviewed an early manuscript. H.C. Brooks of the Oregon Department of Geology and Mineral Industries and A.R. McBirney of the University of Oregon reviewed a later draft. Financial support for this research project included a Geological Society of America Penrose Grant in both 1971 and 1972. I also wish to acknowledge support, both financial and in geologic interpretation, from the Oregon Department of Geology and Mineral Industries.

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Wheeler, G.R., 1976, Geology of the Vinegar Hill area, Grant County, Oregon: Seattle, Wash., University of Washington doctoral dissertation, 94 p. □

Short course on diatoms to be taught in Canada

L. H. Burkle of the Lamont-Doherty Geological Observatory will teach a two-day short course on diatoms on March 8th and 9th, 1982, at the University of British Columbia. The course will deal with the morphology, paleoecology, and fossil record of this important fossil group, with particular emphasis on the North Pacific. For details contact Paul L. Smith, Department of Geological Sciences, University of British Columbia, Vancouver, B.C., Canada, V6T 2B4. □

OIL AND GAS NEWS

Willamette Valley:

After drilling to a depth of 6,005 ft, Reichhold Energy Corp. has abandoned its Bagdanoff 23-28 near Woodburn. The well, the deepest ever drilled by Paul Graham Drilling Co., was plugged on November 17, 1981, after four weeks of drilling.

Clatsop County:

Oregon Natural Gas Development Co. drilled to a total depth of 10,006 ft on its Johnson 33-33 south of Svensen. The ROVOR rig that drilled the hole has been moved to Yakima, Washington, for Shell Oil Co., and the well is now being tested using a John Taylor Drilling rig.

Douglas County:

As we reported last month, Florida Exploration Co. has applied to drill a 10,000-ft well in sec. 4, T. 21 S., R. 6 W. Because the well will be closer than 500 ft from a spacing unit boundary, a hearing was held December 7, 1981, to hear comments by the neighboring mineral rights owners. The following day, the Governing Board of the Oregon Department of Geology and Mineral Industries agreed to hold the hearing open for an additional 30 days so that further written comments could be accepted. A decision on whether to grant the permit is expected from the Board on January 25, 1982.

Mist Gas Field:

American Quasar Petroleum has once again drilled in the Mist Field after an absence of several months. Benson Timber 8-14 was spudded November 21, 1981, in sec. 8, T. 6 N., R. 4 W., and in only a few days a total depth of 2,196 ft was reached. The hole was dry, however, and was abandoned on November 27, 1981.

Proposed changes to Administrative Rules:

Due to legislation passed by the 1981 session of the Oregon Legislature, the Department of Geology and Mineral Industries is proposing changes to its Administrative Rules governing oil and gas drilling. Comments have been gathered from industry and from other state agencies on the first draft of the rules. The proposed rules in draft form will soon be publicized, and a date set for a hearing on the rules.

Proposed changes to the rules include:

1. New definitions.
2. Change in information on application to drill.
3. Change in time from 20 to 60 days for filing data.
4. Possible extension of 2-year confidentiality of data.
5. Change in requirements for directional surveys.
6. Removal of mandatory hearings for spacing rule exceptions.
7. Change in abandonment plugging requirements.

Division of State Lands schedules lease sale:

The Oregon Division of State Lands has scheduled its next lease auction for February 24 and 25, 1982, to be held at the Marriott Hotel in Portland. Nominations for over 125,000 acres in 14 counties have been received. The counties with the most acreage nominated include Malheur, Gilliam, Harney, Lake, Marion, Clatsop, and Clackamas. Other counties receiving nominations are Columbia, Morrow, Umatilla, Union, Washington, Yamhill, and Sherman.

The auction will begin at 9 a.m. each day. Questions about the lease sale may be directed to the Division of State Lands, phone (503) 378-3805. □

Thermal springs near Madras, Oregon

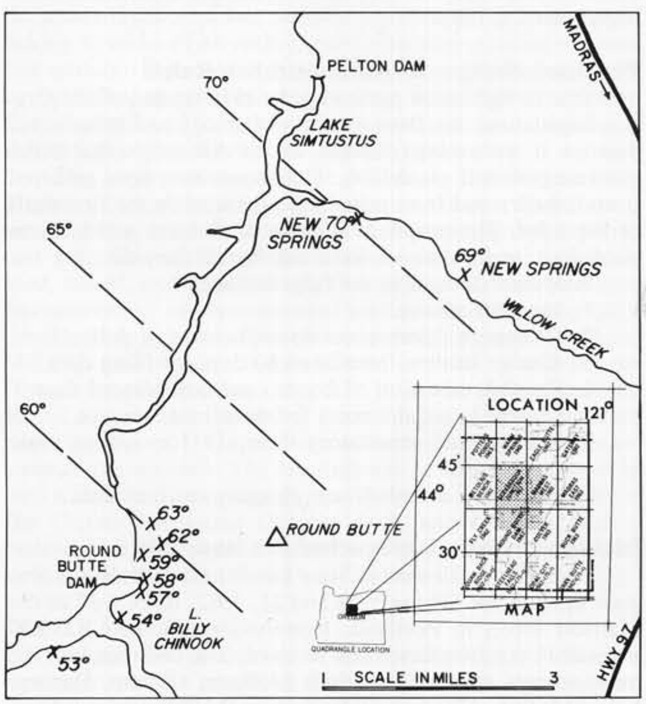
by Mel S. Ashwill, 940 SW Dover Lane, Madras, OR 97741

Before Portland General Electric Company (PGE) constructed Pelton Dam (late 1950's) and Round Butte Dam (completed 1964) on the Deschutes River near Madras, Oregon, it was known that water from Round Butte Spring, located about 0.8 km (0.5 mi) downstream from Round Butte Dam, was of a higher temperature than other springs in the area. Preparatory studies for the construction of Round Butte Dam identified at least seven more low-temperature thermal springs in the vicinity.

In the first few years following the filling of Lake Simtustus (Pelton Dam), among the many new springs that appeared about its perimeter was a group of seven new thermal springs which became activated approximately 3.5 km (2.2 mi) east of the impoundment. These springs are just above creek level in Willow Creek Canyon and approximately 91 m (300 ft) above the normal pool level of the lake. The subsequent filling of Lake Billy Chinook (Round Butte Dam) resulted in more new springs, including another group of seven new thermal springs at the mouth of Willow Creek Canyon, about 61 m (201 ft) above Lake Simtustus level. This sequence of events was reported by several local residents and was confirmed by Vic Bacon (1980, personal communication), who was project manager during the construction of Round Butte Dam.

In the spring and summer of 1980, this author was guided to the sites of these new thermal springs by Bill Robinson and Ray Grant of Madras. At that time, temperature measurements and photographs were taken.

The area discussed in this paper lies in Jefferson County, Oregon, approximately 11 km (7 mi) west of the city of Madras. Thermal springs emerge along both banks of the Deschutes River, with the majority on the east bank, and also in lower Willow Creek Canyon. The southwesternmost spring of the group is in the SE¼ sec. 22, T. 11 S., R. 12 E. The northeasternmost site is in the NW¼ sec. 32, T. 10 S., R. 13 E. An intensive search for further extensions of the thermal area by means of spring- and well-temperature measurements was not made by the author; the bounds of the area as well as the direction of thermal gradients remain undetermined.



Location and temperatures (in degrees Fahrenheit) of selected springs in the area. Direction of gradient lines is an estimate only, based on direction of recent linear features locally and correlation with Pipp Spring, a 61°F spring just west of the area shown.

Group of seven thermal springs (left center) emerging from base of thick basalt flow at mouth of Willow Creek. Streams from springs descend steeply to road level.

Previous studies of the thermal springs in existence prior to construction of the dams include those of E.T. Hodge (1958) and of other geologists who did work for Portland General Electric Company (Bechtel Corporation, 1958).

The geologic units in the area are middle Miocene to early Pliocene Deschutes Formation, volcanic rocks, and Quaternary sediment, all of Farooqui, Beaulieu, and others (1981) and Farooqui, Bunker, and others (1981). Exposures consist of sedimentary beds of fluviatile and lacustrine origin, with interbedded basalt flows, mudflows, ash flows, and pyroclastic material. Basaltic lava flows form a plateau that has been deeply eroded by the Deschutes, Crooked, and Metolius Rivers. Above the basaltic plain rises Round Butte, a shield volcano capped by a cinder cone dated at 5.9 ± 0.6 m.y. (Farooqui, Bunker, and others, 1981).

The first of the two groups of new springs visited by the writer includes seven springs and is in the SW¼ sec. 30, T. 10 S., R. 13 E., about 61 m (201 ft) higher than and immediately above the place where Willow Creek enters Lake Simtustus.

The waters issue from the lower contact of a thick basaltic lava flow on the south face of the canyon. All of the springs are at a uniform elevation along a total distance of approximately 160 m (525 ft). Temperatures of the springs vary between a minimum of 19° C (66° F) and a maximum of 21° C (70° F). Measurements were made on April 24, 1980. The collective waters of the springs flow over a 1-m (3-ft)-wide weir at a depth of 7.6 cm (3 in). Temperatures of other springs in the area are 12° C (54° F).

The microclimate provided by the combined effects of the warm water and the sheltered, north-facing slope has resulted in a surprising change in flora, even though the new springs have only existed for approximately 15 years. The typical low desert plant community of bunch grass, rabbit brush, sage-

Grass, sage brush, and juniper typical of the area grow to within 30 m (100 ft) of thermal springs at mouth of Willow Creek.

Sword fern in immediate area of thermal springs at mouth of Willow Creek.

brush, and juniper occupies the slope to within 30 m (100 ft) of the springs. The flora in the immediate vicinity of the springs, however, is reminiscent of Cascade province types. Plants growing here include sword fern, willow, wild raspberry, elm, and a luxuriant growth of miner's lettuce.

The second group of seven springs is about 3 km (2 mi) farther upstream on Willow Creek, in the NW¼ of sec. 32, T. 10 S., R. 13 E. The area is on private land, and permission is required to enter. All of these springs come from the lower contact of a lava flow along the north bank of Willow Creek and extend over approximately 275 m (907 ft). There are two exceptions: One spring is at the same level, but on the south bank of the stream; another spring emerges on the north bank, but approximately 30 m (100 ft) above the other springs. Several of the larger springs are in grottoes formed by erosion of material from beneath the lava flow. Some of the grottoes may be parts of lava tubes. The temperatures of this group range from 17° C (62° F) to 21° C (69° F). These measurements were made July 20, 1980.

In the center of this line of springs there is one additional spring with a lower temperature of 13° C (55° F). This colder water spring is reported to have been in existence for an unknown number of years prior to the construction of either of the local dams.

ACKNOWLEDGMENTS

In addition to the two previously mentioned guides, thanks are due to Steven Loy, General Manager, Public Relations, PGE, Portland, Oregon, for supplying certain data and for reviewing the manuscript, and to Harry Phillips of Warm Springs, Oregon, and Vic Bacon of Madras, Oregon, retired manager of the PGE facility at Round Butte, for verification of ages of the springs.

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Hodge, E.T., 1958, The proposed Round Butte dam and reservoir: Portland, Oreg., Portland General Electric Company, 46 p. □

Northwest Mining Association elects new leaders at 87th annual convention

The Northwest Mining Association (NWMA) elected new leaders Wednesday, December 2, 1981, to guide its more than 2,500 members from five western states and western Canada.

On the eve of the NWMA 87th annual convention, NWMA trustees unanimously selected Keith J. Droste to replace 1981 president John C. Balla. Droste, former general manager of Day Mines, Inc., before its recent takeover by Hecla Mining Co., currently holds the position of manager, new mine development, for Hecla.

The trustees also elected Joseph McAleer, Molycorp, and George Tikkanen, Cominco American, Inc., as first and second vice presidents. Spokane attorney John L. Neff and David M. Menard, Seattle-First National Bank, were re-elected secretary and treasurer.

Newly elected trustees include John Beaulieu, Oregon Department of Geology and Mineral Industries; Earl H. Beistline, University of Alaska; Lovon Fausett, Sr., Wallace Diamond Drill Co., Inc.; Bernard J. Guarnera, Boise Cascade Corp.; Mike W. Keevan, R.A. Hanson Co., Inc.; Ernest H. Gilmour, Eastern Washington University; Earl D. Lovick, W.R. Grace and Co., Inc.; Lynn A. Pirozzoli, Hecla Mining Co.; Robert A. Lothrop, J.R. Simplot Co.; and John C. Balla, ASARCO, Inc. □

USGS maps increase in price

Due to a directive from the U.S. Geological Survey (USGS), USGS maps sold by the Oregon Department of Geology and Mineral Industries have gone up in price as of December 1, 1981. New prices: 7½- and 15-minute quadrangle topographic maps, $2; AMS topographic maps, $3.25; Map I-325 (geologic map of Oregon west of 121st meridian), $3.50; Map I-902 (geologic map of Oregon east of 121st meridian), $5; State topographic map, $3.25; and State base map, $3.25. □

Nation's mineral resources assessed in USGS report

A 722-page report that assesses more than 60 mineral and energy commodities in the United States and describes the importance, availability and possible future sources of each commodity, has been reprinted and is again available from the U.S. Geological Survey (USGS), Department of the Interior.

The report was written by USGS scientists with nearly 2,300 person-years of experience in the geology of mineral resources. The report, compiled in 1972 and published in 1973 as part of Interior's response to the Mining and Mineral Policy Act of 1970, is now being reprinted for the third time.

According to Don Brobst, one of the two co-editors of the report, and a recently retired geologist at the USGS National Center, Reston, Va., "The major patterns in resources seen in 1973 have not changed greatly overall in the last decade. With few exceptions, the geologic sources of most commodities are still as they were a decade ago, and as a result, this report is still as vital and germane today as it was 10 years ago."

The types of commodities described in the report range from major metals and industrial minerals, such as copper, silver, chromium, manganese and fluorspar, to commodities of greatly varied geologic nature, such as pigments or gemstones, and commodities that are currently of minor importance, such as scandium or thallium.

In his chapter on mineral resource estimates and public policy, Dr. Vincent E. McKelvey, former director of the USGS, now retired, describes the magnitude of the United States' mineral supply and consumption problem. "...in attaining our high level of living in the United States, we have used more minerals and mineral fuels during the last 30 years than all the people of the world used previously," McKelvey said. "This enormous consumption will now have to be doubled just to meet the needs of people now living in the United States through the remainder of their lifetime, to say nothing about the needs of succeeding generations, or the increased consumption that will have to take place in the lesser developed countries if they are to attain a similar level of living."

Some commodity highlights from the report:

- *ALUMINUM:* Industrial use in the U.S. is about 18 million tons of bauxite and alumina annually, but the nation produces only 13 percent of its needs. There are enormous (250-300 million tons) low-grade resources, but they cannot be recovered without major technological breakthroughs or higher costs.
- *CHROMIUM:* Domestic resources of this indispensable industrial metal—used for plating, to harden and toughen steel, and in stainless steel, cutting tools, and wear-resistant alloys—are low grade, totaling 7 million tons of ore, and represent only about a four to five-year supply. At least 90 percent of the world's known chromium resources are in southern Africa. There is little or no likelihood of discovering significant new domestic resources, and at present, all chromium used (about 430,000 tons of metal annually) in the United States is imported.
- *COPPER:* Of the 2 million tons of copper used annually in the United States, about one-half is used in electrical applications, about one-sixth in construction, and one-eighth in industrial machinery. In 1971, the nation imported only 6 percent of its copper, but known domestic economic resources (76 million tons of copper metal) are adequate for about 45 years at current rates of consumption. Adequate supplies for a longer time or increased rates of consumption must depend on discovery of new deposits and development of extractive methods for very low-grade deposits.
- *GOLD:* The United States produces only about 1.8 million ounces of gold a year, representing only about one-third to one-quarter of its needs. About 40 percent of the production is a byproduct from the refining of other metals, chiefly copper. It is unlikely that the nation will become self-sufficient in meeting its gold needs in the foreseeable future. Production from vast (about 300 million ounces) low-grade resources would require solving formidable technological and legal problems.
- *MANGANESE:* So essential is manganese to the manufacture of steel, that a simple phrase sums up their relationship: "When we can do without steel, we can do without manganese." The United States has virtually no domestic reserves of manganese. Known resources (960 million tons) are both very low grade and difficult to process. Geologic research might lead to discovery of new high-grade ore deposits in several regions. A promising means of relieving our dependence on foreign sources would require vigorous research to perfect techniques of recovering sea floor nodules, which would also provide a potential "bonus" in copper, cobalt, and nickel.

According to the USGS report, a serious aspect of the mineral supply problem is the extent to which commodity byproducts are literally being wasted because there is no apparent economic incentive for recovering them during ore processing. Some elements go into slurry ponds, some into slags, and some up the flues. These commodities include vanadium in iron deposits, selenium, tellurium, and gold lost through in-place leaching of copper deposits; fluorine, vanadium, uranium, and rare earths in marine phosphate deposits; cadmium, bismuth, and cobalt in lead ores; and several metals in coal ash.

Maps showing the distribution of known deposits of many commodities in the United States are available in the mineral resource map series of the USGS. A free listing showing the minerals covered in this series can be obtained by writing: Branch of Geologic Inquiries, U.S. Geological Survey, 907 National Center, Reston, Va. 22092.

The report, titled "United States Mineral Resources," and published as USGS Professional Paper 820, may be purchased for $17.00 from the U.S. Geological Survey, Branch of Distribution, 604 South Pickett St., Alexandria, Va., 22304 and over the counter at USGS Public Inquiries Offices in Los Angeles (7638 Federal Bldg., 300 N. Los Angeles St.); San Francisco (504 Custom House, 555 Battery St.); Denver (1012 Federal Bldg., 1961 Stout St.); Dallas (1C45 Federal Bldg., 1100 Commerce St.); Salt Lake City (8105 Federal Bldg., 125 South State St.); Spokane (678 U.S. Courthouse, West 920 Riverside Ave.); Anchorage (108 Skyline Bldg., 508 Second Ave.); Menlo Park, Calif. (room 12, Bldg. 3, 345 Middlefield Rd.); Washington, D.C. (1028 General Services Bldg., 19th and F Sts., N.W.); and Reston, Va. (room 1C402, USGS National Center, 12201 Sunrise Valley Dr.). □

GSOC luncheon meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

January 15, 1982—*Plant and Animal Fossils*: by Leo F. Simon, photographer, retired, and president 1949.

February 5—*China's Ancient Capitals*: by Hazel Newhouse, geographer and recent voyager to China.

February 19—*Canadian Maritime Provinces: Bus Tour*: by Margaret Steere, geologist/editor, retired. □

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COVER PHOTO

Heceta Head, between Florence and Newport on the Oregon coast. This headland is composed of upper Eocene Yachats Basalt pillow breccia and lava, basaltic sandstone and tuff breccia, and massive basalt. A summary of plate-tectonic processes that have shaped the western margin of Oregon is presented in the article beginning on the next page. Photo courtesy Oregon State Highway Commission.

OIL AND GAS NEWS

Willamette Valley:

Drilling activity in the Willamette Valley during 1981 concluded with the logging and plugging of Bagdanoff 23-28 by Reichhold Energy Corporation. The well, located in sec. 28, T. 5 S., R. 2 W., was drilled to a total depth of 6,005 ft.

Three permitted locations that have not yet been drilled still exist for the Willamette Valley: (1) American Quasar Petroleum Company, Chipman 4-14, sec. 4, T. 12 S., R. 2 W.; (2) American Quasar Petroleum Company, Weber Farms 12-22, sec. 12, T. 13 S., R. 3 W.; and (3) Miller Drilling, Bork 2, sec. 26, T. 8 S., R. 5 W.

Clatsop County:

Johnson 33-33, drilled by Oregon Natural Gas Development Company in sec. 33, T. 8 N., R. 8 W., has been drilled to a depth of 10,006 ft. The well was plugged and suspended on January 17, 1982.

Mist Gas Field:

Winter 1982 drilling activity at Mist will include the drilling of Reichhold Energy's Columbia County 41-2 and the redrilling of their 1980 well, Columbia County 12-9. The company will also carry out further drilling in the field during the year. Reichhold has 13 permitted locations that have not been drilled.

Legislation and rules

During the 1981 session of the Oregon legislature, House Bill 2146 was passed, making several changes in the law governing oil and gas drilling in Oregon. To implement this bill, the Oregon Department of Geology and Mineral Industries (DOGAMI) wrote amendments to the Oregon Administrative Rules, Chapter 632. The DOGAMI Governing Board held a hearing in Portland on February 3, 1982, to discuss the proposed amendments.

State Lands lease sale

The Oregon Division of State Lands has scheduled a lease sale for February 24 and 25 at the Marriott Hotel in Portland. Oral bids will be accepted starting at 9:00 a.m. on 313 parcels totaling 116,122 acres in fifteen counties. The counties with the most acreage offered are Malheur, Harney, Gilliam, Lake, Washington, Morrow, and Clatsop.

Persons on the mailing list for auctions will receive information by mail; others may obtain further details by calling (503) 378-3805. □

CONTENTS

Tectonic evolution of the Oregon continental margin

by Ellen T. Drake, School of Oceanography, Oregon State University, Corvallis, Oregon 97331

INTRODUCTION

The northeast Pacific is a unique plate-tectonic region. Movements of the Juan de Fuca Plate, a remnant of the ancient Farallon Plate, seem to have been the cause of many of the processes that have taken place at the Oregon continental margin. The complexity of the tectonic processes of the region is a challenge for investigators to unravel.

This paper is a synthesis of literature published on the tectonics of the region. From this synthesis emerges an integrated view of the sequence of tectonic events that have taken place in the margin off the Oregon coast. A scenario of the Cenozoic tectonic history of this area is included.

SUMMARY OF EVIDENCE FOR UNDERTHRUSTING AND CONTINENTAL ACCRETION

Figure 1 shows the current view of the tectonic setting of the area, Figure 2 the major physiographic features. Geophysical evidence generally substantiates the plate-tectonic interpretation of the major features in the northeast Pacific as outlined in these figures. Underthrusting of the continental margin has apparently been the central element in characterizing regional tectonics. The crucial problem for many investigators, therefore, has been to demonstrate that oceanic crust has indeed underthrust the continental margin off the coast of the Pacific Northwest and has added to the growth of the continent.

Fossil and sediment evidence is provided by Byrne and others (1966), Kulm and others (1973), Schrader (1973), and von Huene and Kulm (1973). Foraminiferal assemblages from the continental slope indicate that sediments found there were deposited 500-1,000 m (1,650-3,300 ft) deeper than the present depth. Such data are corroborated by radiolarian and diatom stratigraphy. Furthermore, lithology characteristic of the abyssal plain occurs on the slope, suggesting that part of the abyssal plain has been uplifted and incorporated in the slope.

Structure evidence for underthrusting is recorded in subbottom profiles (Byrne and others, 1966) in which anticlines and synclines near the outer continental shelf and upper continental slope indicate compressional forces operating normal to the continental margin. Some continuous reflectors in seismic reflection records obtained during Leg 18 of the Deep Sea Drilling Project (DSDP) on the Oregon lower continental slope indicate upwarping of Astoria Fan sediments to form the first fold of the slope. Similar structures occur in Washington and northern California (Silver, 1969, 1972, 1975; Carson, 1977).

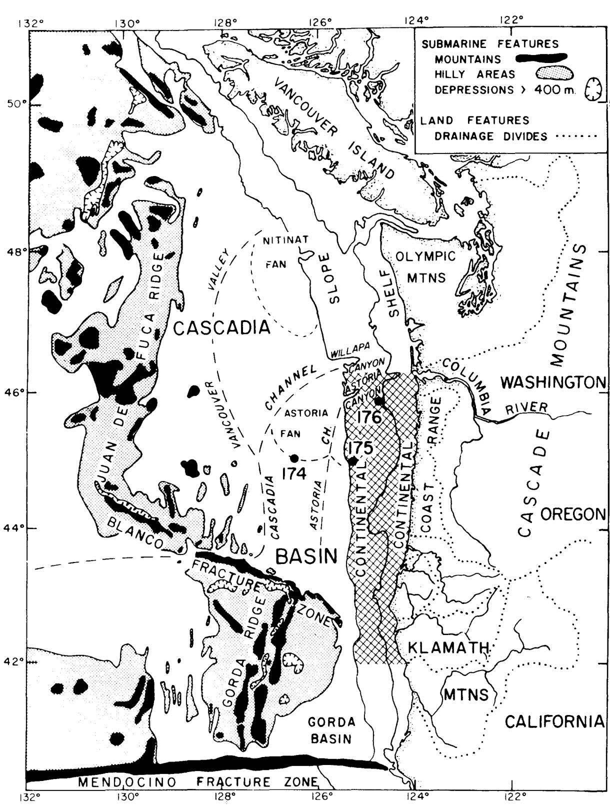


Figure 1. Major physiographic provinces of western Oregon, the continental shelf, the continental slope, and surrounding abyssal features. The cross-hachured pattern delineates the continental shelf area off Oregon. Numbers 174, 175, and 176 refer to Deep Sea Drilling Project sites. From Kulm and Scheidegger, 1979.

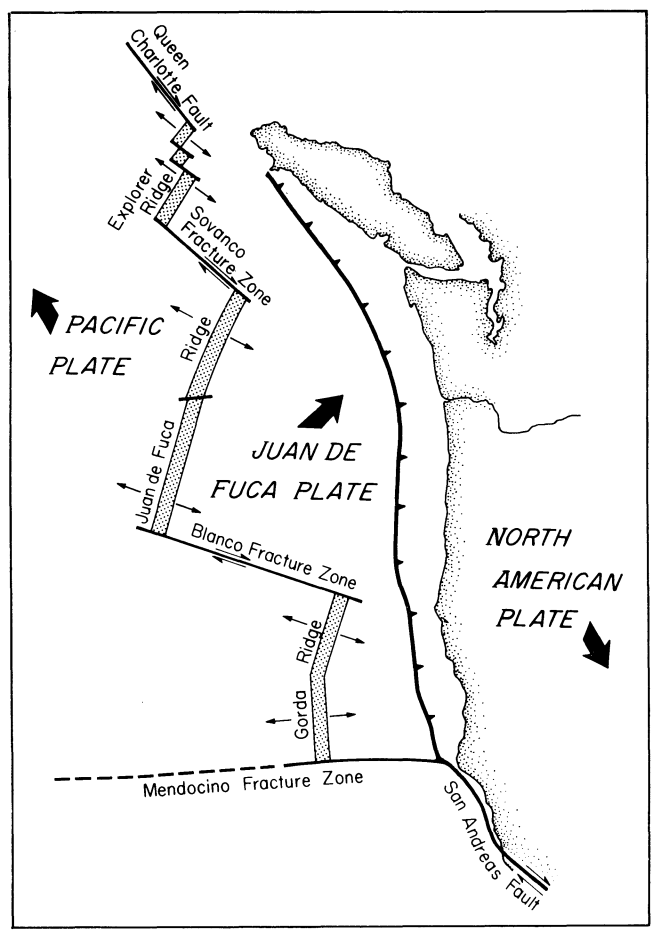


Figure 2. The present view of the tectonic regime of the area showing general directions of relative plate motions of the Pacific, Juan de Fuca, and North America Plates. From Couch and Braman, 1979.

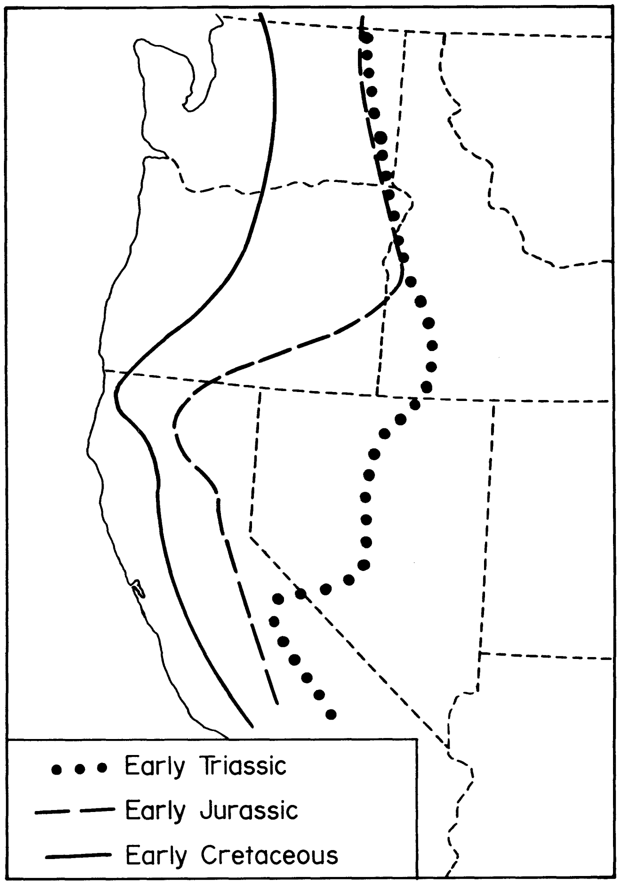


Figure 3. Map showing locations of continental margin at different times during the Mesozoic. From Brooks, 1979.

The classical zebra stripes of magnetic anomalies support sea-floor spreading and underthrusting in this area (Raff and Mason, 1961; Vine, 1966). Emilia and others (1966, 1968) note the large variation in depths of anomaly sources. Furthermore, the extension of magnetic anomalies under the continental slope indicates underthrusting of the oceanic plate. Silver (1972) estimates that approximately 50 km (30 mi) of the outer continental slope may have been formed by accretion in Pleistocene time.

Although several investigators do interpret crustal profiles and gravity anomalies as indicative of subduction at the continental margin of the Pacific Northwest (Dehlinger and others, 1968; Couch, 1972a, b; Couch and others, 1978), other investigators (Maxwell, 1968; Morgan, 1968; MacFarlane, 1974) draw different conclusions, proposing instead that extensional forces cause vertical movements or, alternatively, that compressional forces result in horizontal movements.

Earthquake data also seem to be inconclusive in terms of subduction in the Pacific Northwest today because of the absence of a well-defined Benioff zone. Most authors, however, agree that subduction has taken place in the geologically recent past. Atwater (1970) speculates that the relative youth and high temperature of the Juan de Fuca Plate result in few deep earthquakes. Also, the high rate of sedimentation along the coast, according to Kulm (1979, personal communication), may actually lubricate the subducting block, allowing it to underthrust without great seismic disturbance.

Heat-flow data (Blackwell and others, 1973; Keen and Hyndman, 1979) generally support the concept of subduction along the Pacific Northwest coast. Heat flow across subduction zones characteristically shows (1) a band of low heat flow extending from the trench to the volcanic arc (about 200 km [120 mi] inland) that is caused by the cold, sinking oceanic lithosphere, and (2) a zone of much higher than normal heat flow further inland caused by the upwelling magma and convective heat from the sinking slab which starts to melt at about 100 km (60 mi) depth. The volcanic line, the Cascade Range, represents the transitional zone from low to high heat flow and also corresponds to a transition from high to low Bouguer gravity anomalies.

Volcanism, at least until the late Oligocene, was predominantly andesitic and is related to the evolution of a low-dipping imbricate subduction zone. Morgan (1968) and Christiansen and Lipman (1972) believe that the Cascade Range is near a state of extinction. They suggest that the underthrusting plate at the coasts of northern California, Oregon, and Washington is becoming smaller, increasingly fragmented, and partially coupled to the North American Plate.

Most of the various lines of evidence, therefore, indicate that subduction and continental accretion are occurring, or at least have occurred in the recent past. But how long have these processes been going on, and how much have we added to our continental margin?

Based on the successively younger belts of ultramafic rocks westward, Maxwell (1974) concludes on a large scale that starting in late Proterozoic time the continental margin of the craton grew westward as a result of sedimentation, orogeny, and continental accretion. All of Oregon, in fact, seems to have been created by a series of island arcs and continental accretion since the Triassic (Figure 3) (Brooks, 1979).

A MODEL OF THE TRENCH INNER SLOPE: THE IMBRICATE THRUST MODEL

By the early 1970's, some investigators began to feel the need for a new model for interpreting the barrage of data concerning the dynamics of plate convergence at continental margins. Seely and others (1974) constructed a model of the trench inner slope which they believe is applicable to many parts of the world. Figure 4 shows the location of the trench inner slope in relation to the other major features of the fore arc.

Seely and others (1974) maintain that the trench inner slope is structured by thrust faults and compressional folds, a conclusion that had been reached by some investigators cited previously. Evidence for uplift of sediments in such locations has also been reported. The structure is a result of underthrusting of the oceanic plate. The outer highs are the most prominent expression of compressional deformation caused by the underthrusting. Seely and others (1974) demonstrate with examples from the mid-America trench that the thrust faults become progressively older and more steeply dipping in a landward direction, away from the trench. The most active faults are at the foot of the trench slope. The progressively steeper

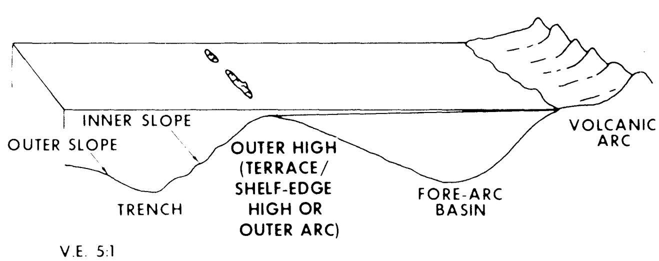


Figure 4. Location of the trench inner slope in relation to the other major features of the fore arc. From Seely and others, 1974.

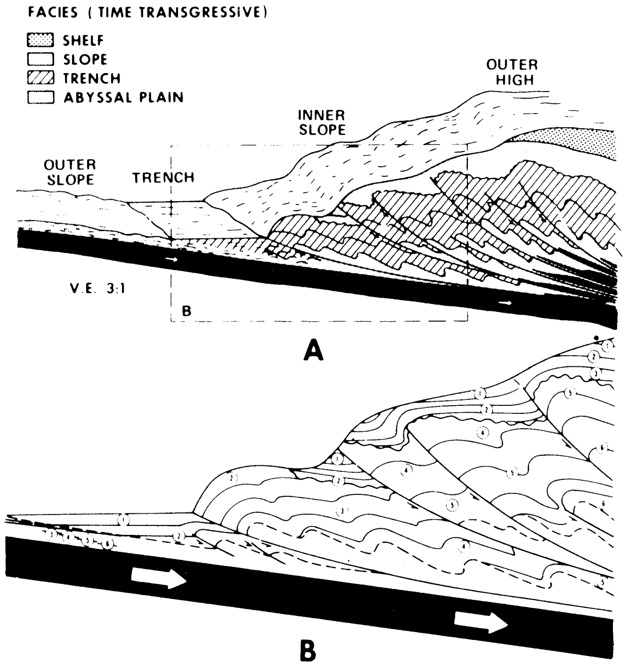


Figure 5. Trench margin model showing landward-dipping, concave-upward thrust faults. A = *facies pattern,* B = *time stratigraphy. From Seely and others, 1974.*

dip of the thrust faults is attributed to the insertion, at the foot of the trench inner slopes, of wedge-shaped slices displaying asymmetric folds between closely spaced, landward-dipping, concave-upward thrust faults (Figure 5). As the lower slices underthrust the older wedges, they push the latter higher on the inner slopes, tilting them so that the increasingly older thrusts have increasingly steeper landward dips.

Slumping of the lower reaches of trench inner slopes contributes to the trench turbidite sequence of sediments. Where slumping does not remove and destroy the tops of folds and thrusts, perched basins may form upslope from the prominences. Sediment accumulation is generally more likely on the upper parts of most trench inner slopes, where thrust activity has diminished or stopped, than on the lower parts.

The ratio between the rate of trench sedimentation and the rate of underthrusting seems to determine the volume of trench sediments (Dickinson, 1973). Where the rate of sedimentation is higher than the rate of underthrusting, a greater volume of sediment is present; where the sedimentation rate is lower, a smaller volume of sediment is present. Where both the sedimentation and underthrusting rates are high, rapid continental accretion results.

In cases of rapid continental accretion, seaward-building of the trench inner slope is coupled with the outbuilding of the shelf, which includes slope sedimentation on top of the "thrust stack." If underthrusting stops while the high rate of deposition continues, sediments may accumulate in the trench and on the trench inner slope. These sediments may then also be structured with thrusts and folds when underthrusting resumes. To add to the complexity of the situation, plutonic intrusions may occur locally between the volcanic arc and trench.

As Seely and others (1974) note, the trench inner slope model, or the imbricate thrust model, gives insight into the facies and time-stratigraphy found on many slopes, the volume of sediments in various trenches, the rate of continental accretion, thrust-fault age relationships, and the development of fan structures.

Testing the model

Kulm and Fowler (1974) successfully interpreted the geology of the Oregon continental margin in terms of the imbricate-thrust model of Seely and others (1974). Major features of the Oregon continental margin include (1) late Cenozoic uplift of the entire Oregon continental margin; (2) major erosional unconformities in the sediment section; (3) a sediment-filled synclinal basin which was created by late Pliocene-Pleistocene subsidence of the inner continental shelf; (4) discordant contacts in sedimentary basins on the lower slope, indicating post-orogenic sediment ponding and tectonism contemporaneous with rapid turbidite deposition; (5) incorporation of abyssal plain and submarine fan turbidite deposits into the lower and middle continental slope; (6) older slope sediments exposed on the outer continental shelf; (7) Pleistocene sediments on the lower slope showing age progression from younger at the base to older near the middle of the slope; and (8) exposure of older deposits by slumping of younger material on the lower slope escarpments which were created by rupturing of uplifted trench sediments as they fold over the incoming oceanic plate.

Kulm and Fowler (1974) show that successive stages of imbricate thrusting at the Oregon continental margin over a 2-m.y. period have pushed the abyssal silt turbidites, ancient fan sand turbidites, Astoria Fan sand turbidites, and even pelagic ooze up higher and higher on the slope in a fanning-out process described by the model. Pleistocene sediments on the lower slope thus show an age progression from younger to older upward from the base of the slope.

Tectonic history of the Oregon continental margin in light of the imbricate thrust model

The tectonic history of the Oregon continental margin as interpreted by Snavely and others (1968) and Kulm and Fowler (1974) has the following scenario:

Middle Eocene turbidites (Tyee Formation; also Flournoy Formation of Baldwin, 1974) were deposited at bathyal depths (1,500 to more than 2,000 m [5,000 to more than 6,000 ft]) on top of a thick sequence of middle Eocene pillow basalts and breccia of oceanic tholeiitic basalt composition (Siletz River Volcanics and related units).

The area then experienced a major tectonic episode which resulted in uplift and erosion during the mid-late Eocene, a dominant element of which is imbricate thrusting by the oceanic plate. Volcanism was renewed at this time within the depositional basin (Nestucca Formation, Yachats Basalt, and related units) as well as in the ancestral Cascades to the east, where volcanism continued into late Oligocene time.

The Coast Range was uplifted by late Oligocene time, and thick gabbroic sills were emplaced. Marine deposition then shifted westward. Siltstone and mudstone (Nye Mudstone and related units) were deposited on the Oregon margin during early Miocene time. Thick nearshore sediments were also deposited during the middle and late Miocene (Astoria Formation and related units).

In mid-late Miocene time, another intense period of thrusting occurred, and the marine deposits on the outer continental margin were uplifted. Erosion of these deposits produced a major angular unconformity that is dated at about 10 m.y. B.P., a date which coincides with a period of worldwide change in plate motion. The rate of subduction may also have increased during this time. Parts of the early Eocene oceanic crust with overlying sedimentary deposits were scraped off the descending oceanic plate and uplifted. The scraped-off material may have been uplifted higher at Heceta and Coquille Banks than at other marginal areas. (Positive free-air gravity anomalies characterize both of these banks, suggesting the presence of a denser mass below.)

Silts and clays were deposited on the upper continental slope during the Pliocene and were subsequently folded and uplifted locally to form massive siltstone and claystone submarine banks at the edge of the continental shelf. The folded structures were later covered with Pleistocene sediments. At the same time, subsidence of the inner shelf created a broad shallow syncline which was filled with shallow-water Pliocene and Pleistocene sediments.

By repeated thrust faulting of wedge-shaped slices at the base of the continental slope, late Pliocene to early Pleistocene abyssal fan turbidites were uplifted 1-2 km (0.6-1.2 mi) to a present water depth of about 1,100 m (3,600 ft) on the upper continental slope. During the imbricate thrusting, basins were created on the upper continental margin by the uplifted thrust sheets and filled with fine-grained hemipelagic sediments. As the underthrusting of younger wedges raised the older deposits higher on the slope, the successively older units and their thrust planes dipped progressively more steeply, and the whole stack of thrusts became more concave upward, fanning out as if swinging around a hinge located somewhere below the continental margin and to the east.

Pliocene and Pleistocene turbidites in the Cascadia Basin indicate sedimentation from the continent to the basin during that time. These abyssal-plain turbidites were downwarped 0.5-1.2 m.y. ago, producing a trench at the base of the continental slope; the sediments were then thrust beneath the slope. Deposition of the Astoria Fan started immediately and continued to the beginning of the Holocene.

As thrust faults developed on the eastern edge of the fan, continued underthrusting caused uplifting of wedge slices, producing the ridge-and-trough topography characteristic of the lower continental slope. Rapid continental accretion is postulated for the northern Oregon slope, where the Astoria Fan deposits attain a thickness of greater than 1 km (0.6 mi).

According to Kulm and Fowler (1974), the above chronological sequence of events for the Oregon continental margin demonstrates that this area is characteristic of a fore-arc structure produced by imbricate thrusting. The inner trench slope model of Seely and others (1974), therefore, tests well at the Oregon margin.

In a 1980 publication, Snavely and others provide a revised interpretation of the Cenozoic geologic history of the central Oregon continental margin. In their opinion, the underthrust boundary between the Pacific and North American Plates "jumped" in the middle Eocene from its presumed early Eocene position under or east of the Cascade Range to the present inner continental shelf. The deep marginal basin that formed east of the new underthrust boundary filled with more than 2,000 m (6,600 ft) of middle Eocene turbidite sandstone and siltstone which were later uplifted into the present Coast Range. They maintain, however, that the underthrusting process was "interrupted by major dextral-slip faulting in late middle Eocene and early late Eocene time and by periods of extension during late Eocene to late middle Miocene and late Miocene to early(?) Pleistocene time" (p. 143).

Snavely and others (1980) believe that during the first major dextral-slip faulting (middle Eocene), a lower Eocene graywacke sequence, which must have originated in coastal northern California or farther south, moved northward and was juxtaposed against lower and middle Eocene volcanics (Siletz River Volcanics) on the east along a north-south-trending dextral transcurrent fault. "Late Eocene to late middle Miocene is inferred to have been a period dominated by extension...along the Oregon continental margin...accompanied by regional subsidence and...sedimentation in the marginal basin and in small outer shelf basins." Extrusion of tholeiitic basalts occurred during middle Miocene time.

Uplift of the Coast Range began in middle Oligocene time; gabbro sills were intruded along north-south zones of tensional rifting. Underthrusting resumed in late Miocene time; middle Miocene and older strata were uplifted, folded on the inner shelf, truncated by erosion, downwarped, and then covered by upper Miocene and Pliocene marine strata. Continental accretion and underthrusting continued, and Pleistocene turbidite sands were broadly folded to form two anticlines separated by a syncline. Imbricate, east-dipping low-angle thrust faults cut and uplifted Pliocene and Pleistocene abyssal sediments. Snavely and others (1980) believe, however, that part of the uplift may have been due to diapiric action, an idea expressed earlier by Maxwell (1968) and Dehlinger and others (1968).

SEGMENTATION: AN ADDITIONAL COMPLICATION

The model

Adding to the already complicated scheme of the imbricate thrust model, Carr and others (1974) propose that studies of the focal areas of large, shallow earthquakes occurring along the upper 20-60 km (12-36 mi) of the inclined seismic zones demonstrate the existence of transverse structures across island arcs. These structures divide island arcs into segments about 100-1,000 km (60-600 mi) long which may act somewhat independently of each other. The segments are detected by changes in strike and offsets of trench axes and other geologic structures.

Earthquakes occur when a segment of the overlying plate rebounds after a period of several decades of being elastically deformed by an underthrusting oceanic plate. Depending on the time since the last earthquake, the state of stress can be different in different segments. Deep crustal faults develop in the overlying plate at segment boundaries. These faults could extend from the trench as far back as the volcanic belt. At this distance the descending lithosphere probably cannot affect crustal structures except by magmatic intrusions along the slab.

A segment of underthrusting lithosphere separated from neighboring segments by tear faults can descend into the mantle with a different strike and dip. The deep seismic zone associated with this segment would also have a different strike or dip from that of adjacent segments.

A line of active volcanoes derived from melting of a segment of descending slab would have a different alignment if that part of the slab has a different strike from a neighboring segment. Or if the dip of the slab segment is different, the melt zone could occur at a different distance from the trench, and the volcanic line would also be offset.

The locations of active volcanoes seem to be strongly influenced by the pattern of discontinuities in the deep seismic zone. Catastrophic volcanic eruptions of historic time have frequently occurred at long-dormant volcanoes on inferred segment boundaries. For example, the Krakatau volcano is located at a prominent transverse structural break in the Indonesian Arc. The concentration of volcanoes, therefore, may represent surface clues to the locations of segment boundaries.

Segmentation across the Oregon continental margin

Couch (1977) notes that geologic and geophysical data collected along continental margins where active subduction is occurring yield differences in sedimentary structures along the strike of the continental shelf. These differences, according to Couch, may be due to time-varying differential displacements of segments of the margin during plate subduction. The amount and manner of accretion of oceanic sediments and crust to the continental margin may differ for different segments of the margin. He believes that these differential displacements may be reflected in the configuration of coastal land forms of Oregon and Washington.

From petrologic relationships, eruptive style, and alignment of the Cascade volcanoes, Hughes and others (1980) determine segment boundaries in the Cascade chain. The six or seven segments proposed by these authors vary between 110 and 240 km (66 and 140 mi) in length (Figure 6). The strikes of the segment boundaries are not well defined by distinct topographic or structural features, but they are parallel to the direction of plate convergence, N. 50° E. This direction is oblique to the continental margin and is consistent with the considerations discussed earlier. The authors suggest that when lines that are parallel to the direction of plate convergence are drawn through points of change in strike in the volcanic chain and projected seaward, they seem to intersect the base of the continental slope at points of offset and change in strike (Figure 6).

The same authors then correlate the positions of the volcanoes in relation to the segment boundaries with the volcano categorization of McBirney (1968). The "coherent" large stratovolcanoes that erupt dominantly porphyritic pyroxene andesites with notable absence of rhyolite are all located within the blocks between segment boundaries and on the volcanic front. The "divergent" volcanoes that erupt siliceous andesites and dacites with later basalts and rhyolites all lie at or near a segment boundary. These segment-boundary volcanoes are further grouped into those along the volcanic front and those to the east behind the volcanic front.

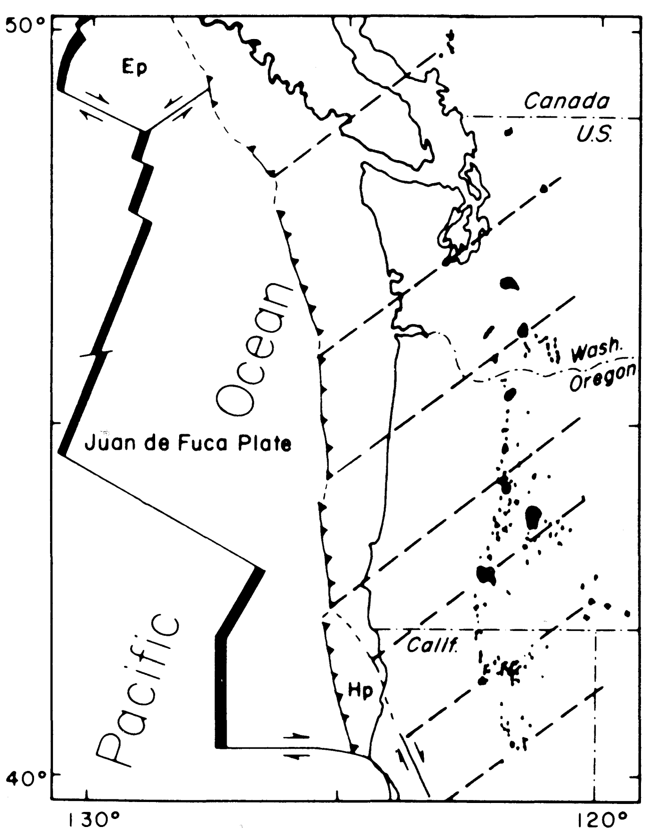


Figure 6. Volcanic segments of Cascades. Black dots represent active volcanoes. Dashed lines represent the surface trace of segment boundaries which strike about N. 50° E. Note that lines intersect base of continental slope at points of change in strike and offsets. HP = *Humboldt Plate;* Ep = *Explorer Plate. From Hughes and others, 1980.*

In this interpretation, however, the petrologic relationships are expressed only as a function of space, without consideration of the passage of time during the Pleistocene. Drake and Couch (1981) show that the segment boundaries themselves have moved as a result of the rotation of the subducting plate during the Pleistocene. The migration of the segment boundaries seems to have exerted a considerable influence on the loci, eruptive history, and petrologic relationships of the High Cascades.

ROTATION: ANOTHER COMPLICATION

Simpson and Cox (1977) conclude from paleomagnetic evidence in Eocene rocks that an Oregon coastal block at least 225 km (135 mi) in length and extending from just north of the Klamath Mountains to north of Newport, Oregon, has rotated 50°-70° east of the expected Eocene field direction (Figure 7). Evidence for rotation is found not only in the lower Eocene Siletz River Volcanics but also in the middle Eocene marine sediments of the Tyee and Flournoy Formations.

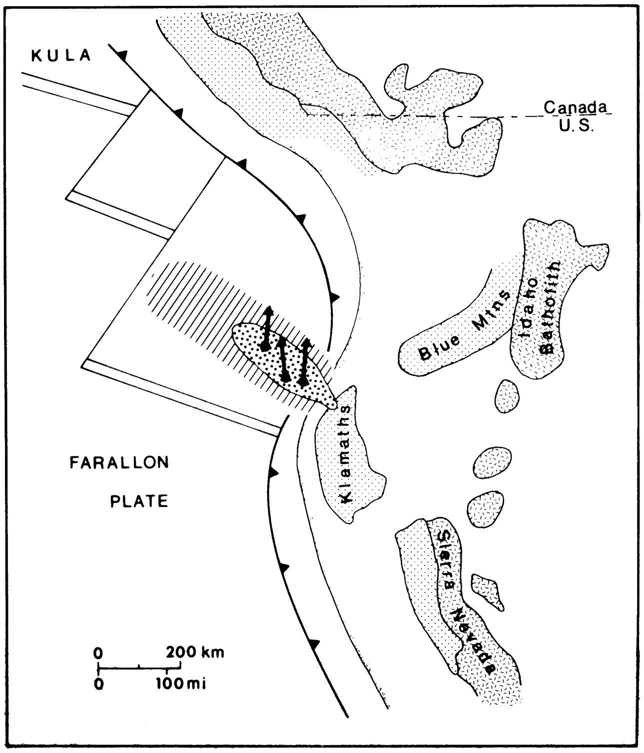
Cox and Magill (1979) claim that, in fact, all of Oregon west of the Cascades has undergone rotation as a single coherent block of lithosphere. They believe that this entire terrain has rotated clockwise 60° about a vertical axis since the lower Eocene. This block constitutes a single microplate extending from the Klamath Mountains of southwestern Oregon to southern Washington. Paleomagnetic studies by Burr and Beck (1977) of the Goble Volcanics in southwestern Washington are consistent with this model. Based on paleomagnetic results from three areas of Eocene volcanic exposure west of the Cascade Mountains in Washington, Beck and others (1979) suggest accretion and clockwise rotation of as many as three thickened oceanic crustal fragments in response to oblique subduction of the Farallon Plate during the early and middle Cenozoic. The amount of rotation shown in the Eocene basalt exposures north of the Columbia River, however, is considerably less than that in the Oregon Coast Range.

Plumley and Beck (1977) describe a constant rate of rotation from 50 to 30 m.y. B.P. in the intrusive rocks of the Coast Range of Oregon. Beck and others (1977) suggest that the Tertiary microcontinental tectonic history of rotation and northward movement in the western North American Cordillera had ceased by Miocene time. Magill and Cox (1981), however, report post-Oligocene clockwise rotation of the Oregon Western Cascades and the Klamath Mountains of about 27° since 25 m.y. B.P.

CONCLUSION: A SUMMARY OF THE CENOZOIC TECTONIC HISTORY OF THE OREGON CONTINENTAL MARGIN

From this review of literature on the tectonics of the Oregon continental margin, a synthesized scenario for the Cenozoic emerges:

In the early Eocene, the Farallon Plate was an oceanic lithospheric plate separated from the Pacific Plate by the East Pacific Rise in the mid-Pacific. A trench was located at the convergent margin along western United States and Mexico between the Farallon Plate and the North American Plate. The trench consumed the Farallon Plate at a rate faster than the rate of its creation at the ridge. Eventually the collision of the ridge and trench caused the annihilation of parts of the ridge when, in mid-Tertiary time, the San Andreas Fault system developed. Subduction south of the Mendocino Fracture Zone then was succeeded by right-lateral transform faulting south of the Mendocino Fracture Zone.



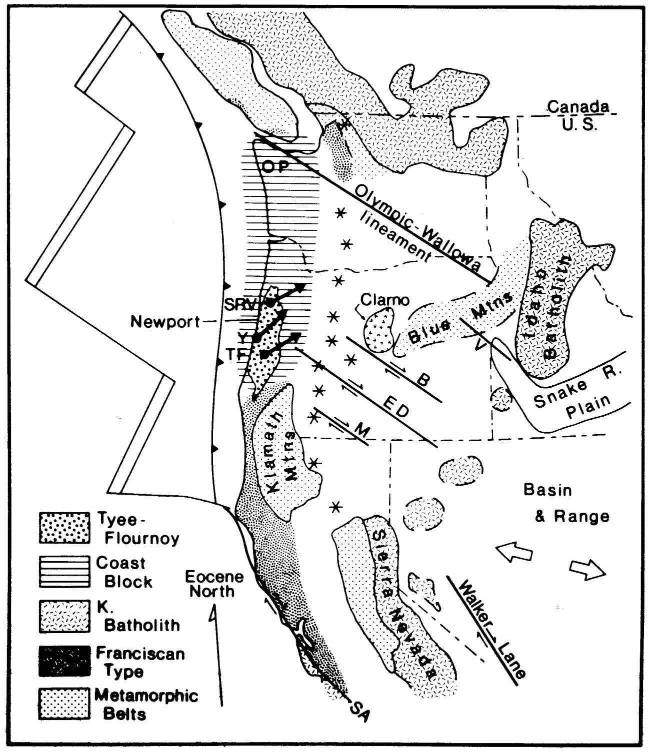


Figure 7. Left: Pacific Northwest in middle Eocene times, showing Coast Range block as part of small plate related to northward migration of Kula-Farallon-North America triple junction. Right: Generalized geologic and tectonic map of northwestern U.S. SRV = *Siletz River Volcanics,* Y = *Yachats Basalt,* TF = *Tyee and Flournoy Formations,* OP = *Olympic Peninsula. Fault zones and lineations:* V = *Vale,* B = *Brothers,* ED = *Eugene-Denio,* M = *McLoughlin,* SA = *San Andreas. From Simpson and Cox, 1977.*

In Oregon, the underthrusting of the Farallon Plate in a direction parallel to the fracture zones caused imbricate thrusting, uplift, and rotation of the continental-slope basin which was filled with lower Eocene volcanics and middle Eocene sediments of the Tyee and Flournoy Formations. The pivot point, at the southern end near the Klamath Mountains, served as a firm anchor for the pivotal motions. At the same time, underthrusting of the oceanic plate caused asymmetrical folds and reverse faults to develop in southwestern Oregon. Volcanism was widespread during this period of intense tectonic disturbance. By late Oligocene time, the Coast Range had rotated almost 60° clockwise and was uplifted, thick gabbroic sills were emplaced, and marine deposition shifted westward.

After the ridge and trench collided south of the Mendocino Fracture Zone, only a remnant of the Farallon Plate was still present north of that zone. Spreading of this much smaller Juan de Fuca Plate continued off Oregon and Washington, but in a different direction and at a different rate. The direction of motion became northeast relative to the continent and oblique relative to the continental margin by Miocene time. Although underthrusting was still sufficient to uplift marine sediments on the outer continental margin and cause continental accretion, the force apparently was no longer great enough to accomplish rotation, given the new geometry and the uplifted mass of the Coast Range.

The subducting block, smaller and less active, began to develop transverse features which caused different segments of the block to act somewhat independently of each other. The differential displacements of the blocks caused deformation of Pleistocene marine terraces.

While underthrusting is possibly still proceeding very slowly at the present time, lateral and extensional movements have also taken place. The Oregon continental margin could be experiencing a transition from compressional underthrusting to strike-slip motions as a result of extensional forces and the coupling of the Juan de Fuca Plate with the North American Plate.

This scenario attempts to take into account phenomena reported by various investigators. It is consistent with the present lack of a well-defined Benioff zone; the presence of a trench, albeit masked by sediments; deformation of slope sediments; heat-flow data; volcanism; gravity and magnetic anomalies, and the processes at one time or another of subduction, obduction, imbrication, segmentation, and rotation. This narrative also considers the subduction process with its many implications and ramifications, including volcanism in the Cascades, as a near-extinction system—the 1980 eruption of Mount St. Helens notwithstanding.

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Oregon counties gain cash from BLM

The State of Oregon and its counties gained $102,530,920.36 from the U.S. Interior Department's Bureau of Land Management (BLM) in the 1981 fiscal year, according to *BLM Facts*, a statistical report published by BLM's Oregon state office.

The largest share of the payment was $96.96 million paid to the 18 western Oregon counties in which revested Oregon and California Railroad grant lands are located. Those counties receive half of the income from management of the O&C lands. Douglas County was the largest recipient with $24,287,413.25, trailed by Jackson County with $15,192,964.69, and Lane County with $14,805,141.73.

Payments in lieu of taxes generated $3.58 million for 34 of Oregon's counties. These payments are appropriated by Congress to assist counties in furnishing services because federal lands within the counties are not taxed. Malheur County was the largest recipient with $477,347. Harney and Lake Counties each drew $328,000.

County shares of mineral lease income provided $1.08 million. Malheur and Harney Counties led with $370,440.93 and $304,471.13, respectively. Counties got $60,402.48 from grazing leases outside grazing districts and $269,795.73 from grazing permits inside grazing districts.

BLM manages 15,718,351 acres of land in all 36 of Oregon's counties. The agency generated $193 million in income from resources and services during the fiscal year, while spending $62,432,648 in managing the resources.

In addition to the mineral and energy resources on its own lands, BLM manages those resources on other federal lands in the state, such as the National Forest system. As the 1981 fiscal year ended, 1,812,823 acres were under leases for oil and gas exploration and 409,087 acres were under leases for geothermal development.

Copies of *BLM Facts* are available from BLM, Office of Public Affairs, 729 NE Oregon St., PO Box 2965, Portland, OR 97208. □

Oregon now affiliated with National Cartographic Information Center

The Oregon State Library has joined with the Forestry Department and the Department of Transportation to form a National Cartographic Information Center (NCIC) state affiliate.

NCIC is operated by the National Map Division of the U.S. Geological Survey (USGS) to provide professional information about cartographic data available from federal, state, and commercial organizations to professional users and the general public. To do this, NCIC collects and organizes cartographic data into geographically retrievable indexes, lists, and catalogs. The USGS will provide these data and will train the staffs of the three agencies participating in the Oregon NCIC Affiliate Information Center in how to use the data. The State Library in Salem will be the main point for dissemination of information and material provided by NCIC. The Departments of Transportation and Forestry will provide technical assistance to users and will assist NCIC in acquiring cartographic data from other State agencies and from private organizations in Oregon to broaden the information base.

For additional information, contact Candy Morgan or Craig Smith, phone (503) 378-4502 or 378-4276. □

Clay subject of new book

Ralph Mason, formerly geologist and State Geologist with the Oregon Department of Geology and Mineral Industries, is author of a new book, *Native Clays and Glazes for North American Potters: A Manual for the Utilization of Local Clay and Glaze Materials.* In it he describes the steps necessary to find, mine, and prepare ceramic material. The book assumes no expertise on the part of the reader and includes much practical advice on such matters as use of topographic and geologic maps, locating oneself in the woods, tools, field and studio tests, drilling and sampling, mining programs and costs, beneficiation and processing, glazes, and fluxes.

Mason describes in detail how and why clay forms, as well as where and when to look for it. He has included a glossary of technical terms and a bibliography, part of which is annotated. Appendices contain such information as classification of clays (by geological origin, mineral content, chemical description, physical properties, laboratory tests, statistical and geographic nomenclature, and usage), Mohs scale of hardness, chemical composition of glazes, names and addresses of public agencies that can provide information to the prospector-potter, chemical analyses of kaolinite and illite, sample drillers logs, and hand-grinding devices. The book is also indexed.

Mason has designed this attractive, 163-page book to serve as a practical manual on how to find, collect, and process the raw material for ceramics. He has supplemented the text with numerous drawings of his own to illustrate topics ranging from geology through mining and testing to equipment for processing.

The book sells for $17.95 (paperback with sewn binding) or $24.95 (hard cover) and is available in local bookstores or from Timber Press, PO Box 1632, Beaverton, OR 97075. □

GSOC luncheon meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

February 19—*Canadian Maritime Provinces: Bus Tour*: by Margaret Steere, geologist/editor, retired.

March 5—*Hawaiian Islands*: by Donald Cook, student, Portland Community College.

March 19—*Native Clays and Glazes for North American Potters*: by Ralph Mason, geologist, retired.

For additional information, contact Viola L. Oberson, Luncheon Chairwoman, phone (503) 282-3685. □

USGS Mount St. Helens field office moved

The Mount St. Helens field office of the U.S. Geological Survey has moved from 301 E. McLoughlin Blvd. to new quarters at 5400 MacArthur Boulevard, Vancouver, WA 98661. This is now the address for all Vancouver-based USGS personnel in both the Geologic and Water Resources Divisions. New phone numbers are as follows: Geologic Division, (206) 696-7860; Water Resources, (206) 696-7810. Portland, Oregon, numbers for the Vancouver offices are as follows: Geologic Division, 285-0239; Water Resources, 228-5335.

The new USGS facility is called the Cascades Volcano Observatory. □

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COVER PHOTO

Charlie Stinson of Northwest Natural Gas installs pressure gauge on American Quasar's Hickey 9-12, Linn County. Article beginning on next page summarizes oil and gas activity in Oregon during 1981.

Notice to contributors

Oregon Geology readers are invited to submit articles about Oregon geology, such as field trip guides, descriptions of geology of state parks, results of student or faculty research, and information on interesting mineralogical or paleontological finds. Both technical and general interest articles will be published. Authors of technical articles are urged to obtain peer review prior to submittal, and such reviewers should be acknowledged in the article.

1. All material should be typewritten, double-spaced, with wide margins.
2. In general, articles, including tables, artwork, and photos, should not exceed 25 pages in length. Longer articles might be published in two installments.
3. Drafted material must be submitted in final form. If reduction will be necessary, lettering should be large enough to be legible after reduction.
4. Photos should be black-and-white glossy prints. If slides or color prints are the only photos available, consult with the editor.
5. All artwork and photos must be clearly marked. Figure references should be placed in appropriate places in the text. A separate typed list of figure captions should accompany the article. All artwork and photos become the property of the Department, unless other arrangements are made prior to publication.
6. Consult U.S. Geological Survey *Suggestions to Authors* (6th ed.) for questions of style. Authors are responsible for accuracy and completeness of citations. Cited references should be in USGS format.
7. Except for units of measurement, do not abbreviate.
8. Each author (or first author in the case of multiple authorship) will receive 20 complimentary copies of the issue of *Oregon Geology* in which his or her article appears. □

Number of mining claims to pass 50,000

The Oregon State Office of the Bureau of Land Management (BLM) will soon record its 50,000th mining claim. BLM is the agency with which miners must register their claims, if the claims are located on federal land. By the end of January, slightly more than 49,800 of the claims had been recorded.

"We've been averaging 10,000 claims a year," said Diane Buckley, miscellaneous documents examiner. "It ranges from a low of about 400 a month to 1,300 or 1,400. Summer and fall are the busiest times of the year."

The Oregon State Office is responsible for recording claims in both Oregon and Washington. Two to three times as many claims are from Oregon than from Washington, probably because Oregon has much more federal land, Buckley said. □

—BLM News, Oregon and Washington

CONTENTS

Oil and gas exploration and development in Oregon, 1981

by Dennis L. Olmstead, Petroleum Engineer, Oregon Department of Geology and Mineral Industries

ABSTRACT

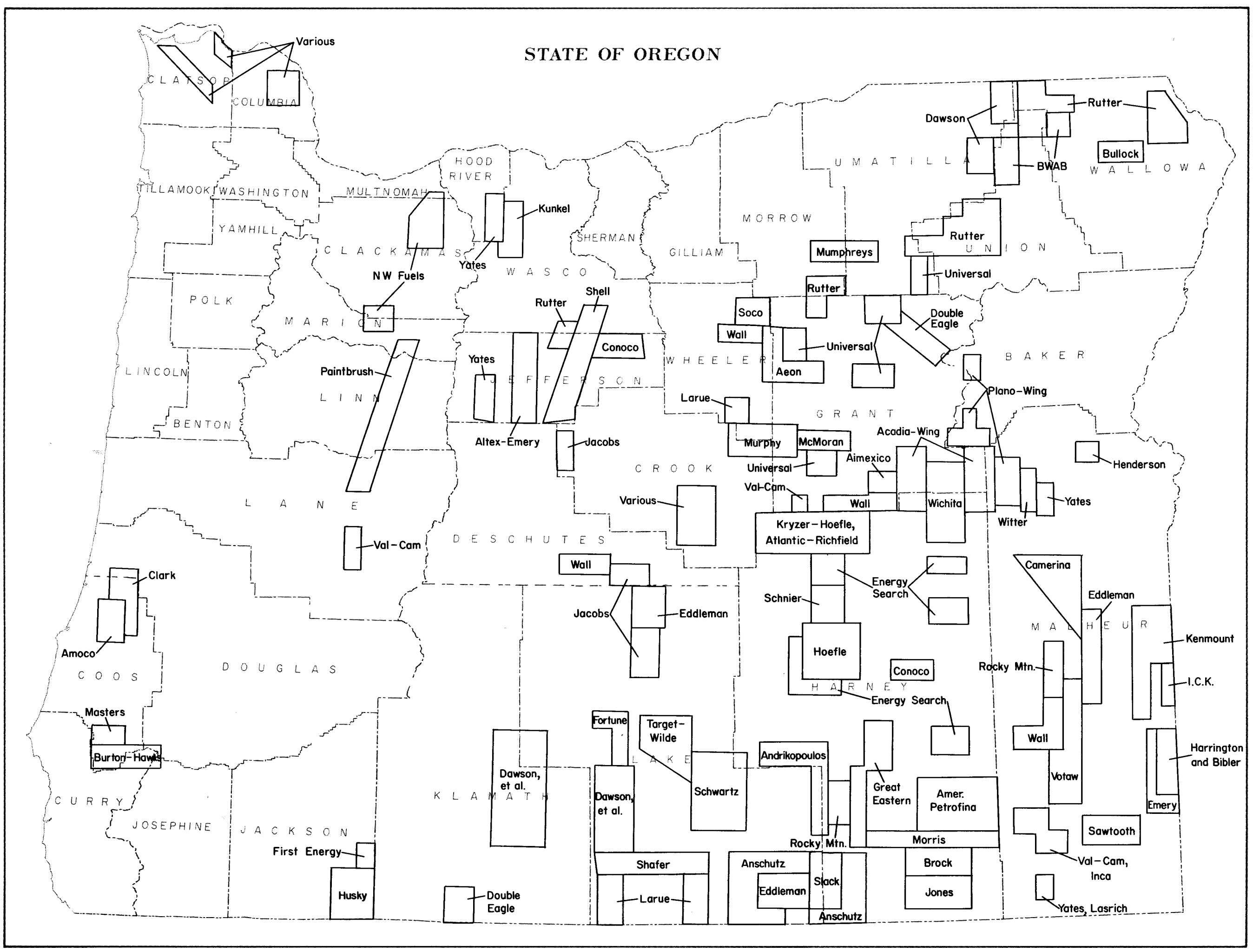
In 1981, acreage leased in Oregon for oil and gas drilling far exceeded that of previous years. By the end of the year, over 4 million acres were estimated to be under lease. In the central, eastern, and southeastern parts of the state, leasing took place in areas which saw little or no interest in past years. Such widespread interest was sparked in part by a deep-drilling program carried out by Shell Oil Company in central Washington. Central Oregon could also be the site of drilling programs in the next few years.

Drilling during the year did not show such a dramatic increase over previous years as did leasing. In fact, the number of holes drilled leveled off, and 1981 had a slight drop from 1980, with a total of 23 holes drilled. This level of activity is likely to continue for the foreseeable future, after the dramatic increase in drilling following the Mist Gas Field discovery. Additional field discoveries could cause another jump in the annual number of wells drilled. The seven active oil and gas operators in Oregon once again concentrated their efforts in the Coast Range and Willamette Valley provinces.

LEASING ACTIVITY

Of the 61,598,720 acres of land in Oregon, 52.6 percent is owned by the federal government, and this fact heavily influenced the oil and gas leasing statistics for 1981. Noncompetitive lease applications were received by the hundreds at the Portland office of the Bureau of Land Management (BLM) throughout the year. Interest shifted this year to central and eastern Oregon, where thousands of unleased acres were still available. Leasing was particularly heavy in the counties of Jefferson, Wheeler, Grant, Umatilla, Union, Lake, Harney, and Malheur. The heavy demand has resulted in far more acreage applied for than actually leased.

During the course of the year, lease applications were filed on more than 12 million acres of federal land in the state. Two million of these acres were leased by the BLM, more than tripling the total federal acreage under lease to about 2,672,000 acres. Noncompetitive leases are issued on properties not previously leased and where there are no known producing geological structures. Most new leaseholds in Oregon are on federal lands.



Oil and gas leases obtained in Oregon, 1981.

The Interior Department has proposed plans to reduce fraud in the lottery system of leasing by increasing the filing fee to $75. Annual rentals would remain $1 per acre for the first five years of the lease but would then jump to $3 per acre for the last five. Interior Secretary James Watt feels this change will slow down the speculation in oil and gas leases and increase participation by those involved with exploration.

The Division of State Lands in Salem leases land belonging to the State of Oregon for oil and gas exploration by holding public lease sales. Two such sales were held during 1981, and over 137,000 acres were leased, mostly in Clatsop, Coos, and Douglas Counties. The high bid was $310 per acre bonus for lands in Clatsop County. Winners of the largest acreages included A. Andrikopoulos, G. Tallmann, X-O Lease Fund, AMOCO, Phillips, J. Ryan, and Gulf Oil. The two sales brought in a total of $3.62 million which is to be distributed to the common school fund, counties where the leases exist, and various state departments.

A new rule governing assignment of state leases was adopted in June 1981. The rule establishes a fee of $50 for assigning a lease and requires that the assignment be approved by the Director of the Division of State Lands.

Columbia County, site of the Mist Gas Field, also held a lease sale during the year. $1.5 million in bonus bids was collected for 73 parcels totaling over 65,000 acres. Parcel sizes ranged from 100 acres up to as much as 1,200 acres. ARCO was the most active bidder at the sale, taking 24 parcels. The high bid, however, was a $93-per-acre offer by Nahama and Weagant for 600 acres in T. 7 N., R. 4 W. Exxon and Tenneco were also lease winners with high bids in T. 5 N., R. 5 W. Columbia County specifies a three-sixteenth royalty in their leases.

Rig moving in to drill Diamond Shamrock's Crown Zellerbach 31-17, Clatsop County.

One of the largest lease acquisitions of private land took place in January 1981, when AMOCO leased 2.75 million acres of Weyerhaeuser land in western Oregon and Washington. The lease includes virtually all of Weyerhaeuser's land and runs for three years, with option to extend up to seven years. Much leasing of smaller parcels of private land also took place during the year, mainly in central and eastern Oregon. Lease terms were usually a 10-year term for $1 per acre per year at a one-eighth royalty and a bonus of $5 to $15 per acre.

Longview Fibre held a sealed bid auction of about 2,000 acres of their property in Columbia County, bringing a high bid of $76.25 per acre from Diamond Shamrock. Other companies leasing land included Champlin Petroleum and Gulf Oil. Lease terms were $10 per acre annual rental, three-sixteenth royalty, and five-year primary term.

The total effect of the leasing during the year was a sudden shift of interest to the eastern half of the state, and the addition of around 4 million acres of land under lease.

1981 DRILLING IN OREGON

Oil and gas drilling in Oregon showed a slight drop from a total of 31 exploratory and development wells in 1980 to 22 in 1981. The same operators continued to work in the state: American Quasar (six wells), Diamond Shamrock (three wells), and Reichhold Energy (eight wells). The remaining six wells were divided among five operators: Ehrens Petroleum, John Miller, Oregon Natural Gas, Quintana Petroleum, and Texaco. Table 1 lists all drilling activities as well as new permitted locations that have not yet been drilled.

Total footage drilled during the year also dropped to 105,057 ft, a decrease of 18 percent. The difference can be attributed almost entirely to the lack of redrills in 1981: only one well was redrilled. The average depth of wells, however, jumped from 3,400 ft in 1980 to nearly 4,700 ft in 1981. This is a sign that the industry is more willing to drill thicker sections in Oregon's sediments.

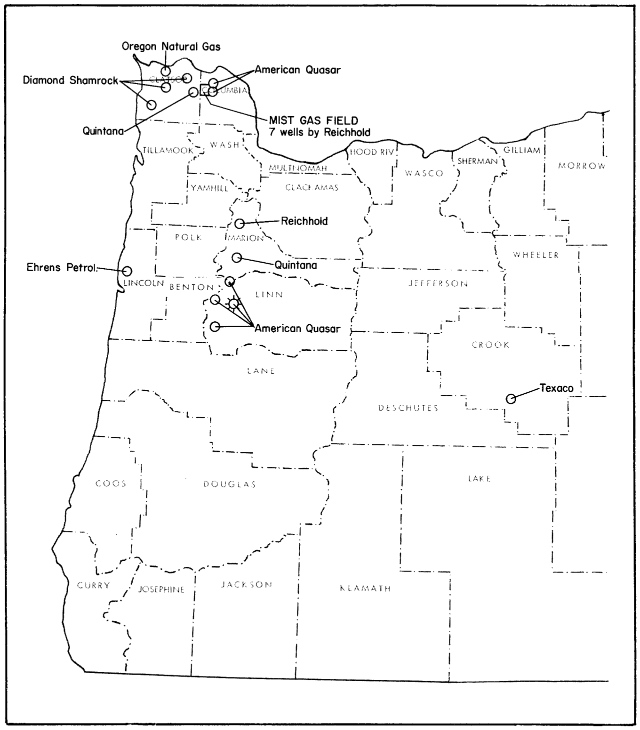
Since the Mist Gas Field discovery in 1979, most drilling has been in or near that field. This was true of 71 percent of all Oregon wells in 1980. But in 1981, only nine wells (41 percent) were field-development or step-out wells; the remaining 13 wells (59 percent) were wildcats in the true sense of the word, which meant they were looking for new fields. The drilling of these wildcat wells demonstrates a gradual change of philosophy among operators here. The combination of deeper drilling and more diversified drilling locations, if continued, increases the likelihood of further field discoveries in Oregon.

The Mist gas discovery of 1979 is having its effect on adjacent areas of the Coast Range. Diamond Shamrock is exploring Clatsop County, with three wells already drilled. The average depth of these wells was 6,550 ft, twice that of most Mist Gas Field wells (Table 1). All three were dry, but Diamond Shamrock will continue to drill in Clatsop County in 1982.

Oregon Natural Gas and Quintana Petroleum also drilled in Clatsop County during the year. These wells, drilled to 10,006 and 7,068 ft, were both dry holes, but Oregon Natural Gas may reenter its hole for redrilling.

WILLAMETTE VALLEY GAS DISCOVERY

The Willamette Valley continues to attract interest from the industry: three different operators drilled six new wells there in 1981. One, American Quasar's Hickey 9-12, in T. 12 S., R. 2 W., was completed as a gas discovery in May. The well



Well locations in Oregon, 1981.

had an initial production of about 200,000 cfd but decreased to 20,000 cfd by September, which led to its abandonment. Oregon's second gas field was short-lived but was encouraging to operators exploring in the Willamette Valley.

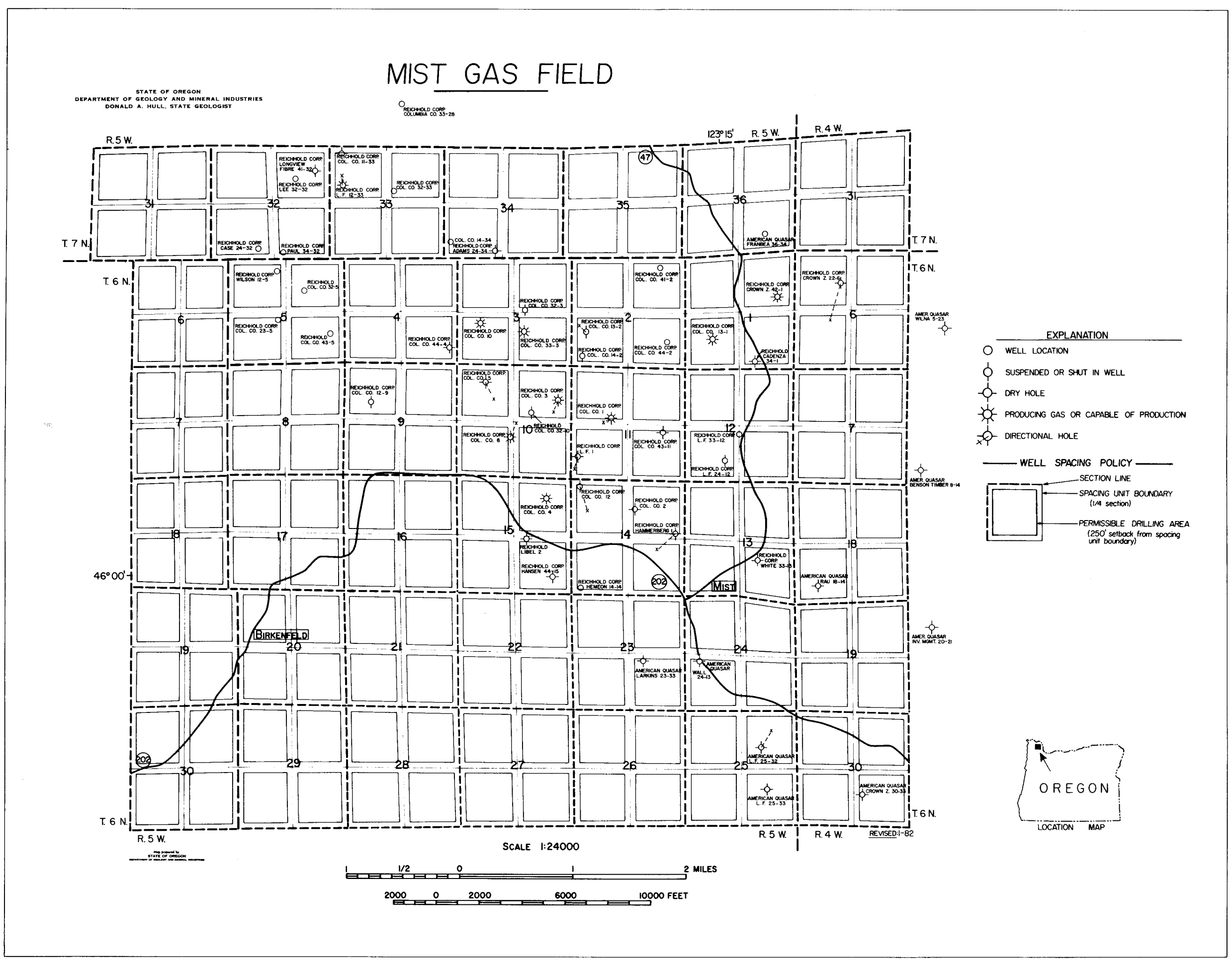
GAS PRODUCTION

Reichhold Energy and its partners, Northwest Natural Gas and Diamond Shamrock, continue to be the only producers in the state. American Quasar temporarily produced gas from Hickey 9-12 near Lebanon (see above), but this production only lasted four months.

Throughout 1981, the gas production came from five wells: Columbia County wells 1, 3, 6, 10, and 33-3, producing from two pools. Production dropped from over 20 million cfd at the beginning to less than 10 million by year's end. While production and zone pressures decrease in these pools, Reichhold Energy has successfully explored for more pools in the field. Columbia County 13-1 in sec. 1, T. 6 N., R. 5 W., was completed in August, but subsequent brief production resulted in water. This well will need remedial work or redrilling to be a commercial producer. At the present time it is shut in.

Later in the year, Reichhold Energy completed another step-out well, Longview Fibre 12-33, in sec. 33, T. 7 N., R. 5 W. With initial production of over 4 million cfd, this well promises to be a valuable addition to the field's productivity. Northwest Natural Gas is constructing a gathering line, and this well will soon be on line.

Two additional pools are known to exist at Mist. In previous years, Reichhold Energy completed Columbia County 4 in



Mist Gas Field, Columbia County.

Table 1. *Oil and gas permits and drilling activity in Oregon, 1981*

Permit no.	Operator and well name	Location	Status and depth TD = total depth (ft) RD = redrill (ft)
123	Reichhold Energy Corp.; Columbia County 11-10	NW¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Permit canceled.
127	Reichhold Energy Corp.; Longview Fibre 34-12	SE¼ sec. 12 T. 6 N., R. 5 W. Columbia County	Permit canceled.
128	Reichhold Energy Corp.; Libel 44-15	SE¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Permit canceled.
130	Reichhold Energy Corp.; Columbia County 21-10	NW¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Permit canceled.
132	Reichhold Energy Corp.; Laubach 34-13	SE¼ sec. 13 T. 6 N., R. 5 W. Columbia County	Permit canceled.
133	Reichhold Energy Corp.; Libel 22-15	NW¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Permit canceled.
134	Reichhold Energy Corp.; Longview Fibre 33-12	SE¼ sec. 12 T. 6 N., R. 5 W. Columbia County	Permit issued.
141	Northwest Exploration Co.; Fish Trap 1	NE¼ sec. 32 T. 28 S., R. 13 W. Coos County	Permit canceled.
142	Reichhold Energy Corp.; Adams 32-34	NE¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Permit canceled.
144	Reichhold Energy Corp.; Adams 23-34	SW¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Permit canceled.
145	Reichhold Energy Corp.; Columbia County 21-34	NW¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Permit canceled.
149	Reichhold Energy Corp.; Columbia County 31-3	NE¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Permit canceled.
150	Reichhold Energy Corp.; Columbia County 42-4	NE¼ sec. 4 T. 6 N., R. 5 W. Columbia County	Permit canceled.
151	Reichhold Energy Corp.; Columbia County 22-3	NW¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Permit canceled.
152	Reichhold Energy Corp.; Longview Fibre 23-12	SW¼ sec. 12 T. 6 N., R. 5 W. Columbia County	Permit canceled.
159	Reichhold Energy Corp.; Sweet 14-1	SW¼ sec. 1 T. 6 N., R. 5 W. Columbia County	Permit canceled.
161	Reichhold Energy Corp.; Bagdanoff 23-28	SW¼ sec. 28 T. 5 S., R. 2 W. Marion County	Abandoned; dry hole; TD: 6,005.
163	Northwest Exploration Co.; Fat Elk 2	NE¼ sec. 11 T. 28 S., R. 13 W. Coos County	Permit canceled.
165	American Quasar Petroleum Co.; Wilna Inc. et al. 6-43	SE¼ sec. 6 T. 6 N., R. 4 W. Columbia County	Permit canceled.
166	Texaco, Inc.; USL-OR 17-1	NE¼ sec. 17 T. 19 S., R. 20 E. Crook County	Abandoned; dry hole; TD: 6,525.
167	Ehrens Petroleum & Development, Inc.; Longview Fibre 1	NE¼ sec. 20 T. 9 S., R. 11 W. Lincoln County	Suspended; TD: 800.
169	Reichhold Energy Corp.; Columbia County 14-34	SW¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Permit issued.
172	American Quasar Petroleum Co.; Hickey 9-12	NW¼ sec. 9 T. 12 S., R. 2 W. Linn County	Abandoned; gas; TD: 4,692.
174	American Quasar Petroleum Co.; M & P Farms 33-24	SW¼ sec. 33 T. 11 S., R. 4 W. Linn County	Abandoned; dry hole; TD: 4,275.
176	American Quasar Petroleum Co.; Franbea et al. 36-34	SE¼ sec. 36 T. 7 N., R. 5 W. Columbia County	Permit issued.
177	Diamond Shamrock; Boise Cascade 11-14	NW¼ sec. 14 T. 7 N., R. 7 W. Clatsop County	Abandoned; dry hole; TD: 7,864.
178	Diamond Shamrock; Crown Zellerbach 11-28	NW¼ sec. 28 T. 5 N., R. 9 W. Clatsop County	Abandoned; dry hole; TD: 5,700.
179	Diamond Shamrock; Crown Zellerbach 31-17	NE¼ sec. 17 T. 6 N., R. 8 W. Clatsop County	Abandoned; dry hole; TD: 6,095.
180	Reichhold Energy Corp.; Columbia County 32-10	NE¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Suspended; TD: 7,807
181	Reichhold Energy Corp.; Columbia County 23-5	SW¼ sec. 5 T. 6 N., R. 5 W. Columbia County	Permit issued.
182	Reichhold Energy Corp.; Columbia County 13-1	SW¼ sec. 1 T. 6 N., R. 5 W. Columbia County	Completed; gas; TD: 3,076.
183	Reichhold Energy Corp.; Hemeon 14-14	SW¼ sec. 14 T. 6 N., R. 5 W. Columbia County	Permit issued.
184	Reichhold Energy Corp.; Longview Fibre 41-32	NE¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Abandoned; dry hole; TD: 2,487.
185	American Quasar Petroleum Co.; Kenneth Wetgen et al. 26-32	NE¼ sec. 26 T. 13 S., R. 4 W. Linn County	Abandoned; dry hole; TD: 2,620.
186	American Quasar Petroleum Co.; Wolverton 13-31	NE¼ sec. 13 T. 10 S., R. 3 W. Marion County	Abandoned; dry hole; TD: 4,555.
187	Reichhold Energy Corp.; Ellis 23-26	SW¼ sec. 26 T. 5 N., R. 4 W. Columbia County	Permit issued.
188	American Quasar Petroleum Co.; Chipman 4-14	SW¼ sec. 4 T. 12 S., R. 2 W. Linn County	Permit issued.
–	Miller Drilling Co.; Bork 2	SE¼ sec. 26 T. 8 S., R. 5 W. Polk County	Application.
190	Reichhold Energy Corp.; Lee 32-32	NE¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Permit issued.
191	Reichhold Energy Corp.; Paul 34-32	SE¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Permit issued.

Table 1. *Oil and gas permits and drilling activity in Oregon, 1981—continued*

Permit no.	Operator and well name	Location	Status and depth TD=total depth (ft) RD=redrill (ft)
192	American Quasar Petroleum Co.; Benson Timber 8-14	SW¼ sec. 8 T. 6 N., R. 4 W. Columbia County	Abandoned; dry hole; TD: 2,196.
193	Oregon Natural Gas Development; Patton 13-33	SW¼ sec. 33 T. 8 N., R. 8 W. Clatsop County	Permit issued.
194	Quintana Petroleum Corp.; Gath 1	SE¼ sec. 16 T. 8 S., R. 2 W. Marion County	Abandoned; dry hole; TD: 6,002.
195	Oregon Natural Gas Development; Patton 21-10	NW¼ sec. 10 T. 7 N., R. 8 W. Clatsop County	Permit issued.
196	Oregon Natural Gas Development; Johnson 33-33	SE¼ sec. 33 T. 8 N., R. 8 W. Clatsop County	Testing; TD: 10,006.
197	Reichhold Energy Corp.; Longview Fibre 12-33	NW¼ sec. 33 T. 7 N., R. 5 W. Columbia County	Completed; gas; TD: 2,407; RD: 2,475.
198	Reichhold Energy Corp.; Columbia County 44-2	SE¼ sec. 2 T. 6 N., R. 5 W. Columbia County	Permit issued.
199	Oregon Natural Gas Development; Patton 32-9	NE¼ sec. 9 T. 7 N., R. 8 W. Clatsop County	Permit issued.
200	Reichhold Energy Corp.; Hansen 44-15	SE¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Abandoned; dry hole; TD: 2,782.
201	Reichhold Energy Corp.; Cadenza 34-1	SE¼ sec. 1 T. 6 N., R. 5 W. Columbia County	Abandoned; dry hole; TD: 2,826.
202	Florida Exploration Co.; Florida Exploration 1-4	NE¼ sec. 4 T. 21 S., R. 6 W. Douglas County	Permit issued.
203	Reichhold Energy Corp.; Columbia County 41-2	NE¼ sec. 2 T. 6 N., R. 5 W. Columbia County	Permit issued.
204	Reichhold Energy Corp.; Case 24-32	SW¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Permit issued.
205	Reichhold Energy Corp.; Columbia County 32-33	NE¼ sec. 33 T. 7 N., R. 5 W. Columbia County	Permit issued.
206	Reichhold Energy Corp.; Columbia County 33-28	SE¼ sec. 28 T. 7 N., R. 5 W. Columbia County	Permit issued.
207	American Quasar Petroleum Co.; Weber Farms 12-22	NW¼ sec. 12 T. 13 S., R. 3 W. Linn County	Permit issued.
208	Reichhold Energy Corp.; Wilson 12-5	NW¼ sec. 5 T. 6 N., R. 5 W. Columbia County	Permit issued.
209	Reichhold Energy Corp.; Columbia County 43-5	SE¼ sec. 5 T. 6 N., R. 5 W. Columbia County	Permit issued.

sec. 15, T. 6 N., R. 5 W., and Crown Zellerbach 42-1 in sec. 1, T. 6 N., R. 5 W. Well 4 awaits repair or redrilling, while production from 42-1 awaits completion of a pipeline connection.

Price on Mist gas, controlled by the Federal Energy Regulatory Commission (FERC), varied during the year from $2.67 to $2.97 per million Btu. The total value for the 5 billion cubic feet of gas withdrawn for the year is $12.8 million. The Mist production comprised about 3 percent of the supply for Northwest Natural Gas, the gas utility serving the area. The remaining gas came from Canada and from New Mexico.

OTHER DEVELOPMENTS

Seismic surveys are a major exploration tool used by the industry prior to drilling. The increase in the number of surveys has paralleled the growth in leasing activity in the state. Several companies have conducted surveys in many parts of the state, notably AMOCO on the Weyerhaeuser property in the coastal counties. In addition, companies such as May Petroleum have made use of magnetotellurics to examine structures beneath the volcanic rocks of central and eastern Oregon. Exxon conducted its seismic studies during November off the coast of Oregon and Washington, rather than onshore. Such geophysical surveys in Oregon suggest that further drilling programs can be expected in future years.

Northwest Natural Gas applied to the Oregon Energy Facility Siting Council for permission to use the Mist Gas Field as a gas storage site. As the two producing pools deplete, the utility is putting plans in place to store 10 billion cubic feet of gas during periods of low demand, to be withdrawn during periods of high demand. After a public hearing, the Siting Council approved the application with the provisions that the project not adversely affect the wildlife habitat or socioeconomic base of the area. The $7.5-million project will include the installation of compressors and one or more large-diameter injection wells. One such well, Columbia County 32-10, has already been drilled.

Base and pipe racks of new ROVOR drilling rig.

Oregon now has its own deep drilling rig. ROVOR, a partnership of Riedel International, Voorhees, and Northwest Natural Gas, has bought and is operating a new 14,000-foot rig. The $5-million rig was used to drill the Oregon Natural Gas well Johnson 33-33 (Table 1) and is now contracted to Shell Oil in Yakima, Washington. The rig was purchased from National Supply in Edmonton, Alberta, and will be used primarily in Oregon and Washington. □

Surface mined land reclamation in Oregon, 1981

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

ABSTRACT

The Mined Land Reclamation (MLR) Program completed a busy and successful year that saw a 17-percent increase in the total acreage bonded; a 34-percent increase in the number of field inspections; major changes in the law, including much stricter requirements for coal and metal mines; and the initiation of an awards program to recognize outstanding reclamation.

LEGISLATION

There were three significant legislative changes to the program. On July 2, 1981, House Bill 2220 of the Oregon Legislative Assembly became law, raising the permit fees for surface mining (provided in ORS 517.800). The Mined Land Reclamation Program is 90 percent funded by the industry which it regulates. The fee increase is designed to maintain the self-sufficiency of the program through the 1981-1983 biennium.

House Bill 2160, which became law on August 17, 1981, contains the other two changes. In one provision which applies to all mined commodities, the threshold figure of disturbed surface requiring a permit is changed from 2,500 cubic yards to 5,000 cubic yards minimum. The major changes included in H.B. 2160, however, apply only to coal and metal mines which receive permits after the effective date of the new law and are designed to place greater emphasis on the protection and rehabilitation of surface and subsurface aquifers, on the recognition and assessment of any toxic or radioactive materials present in any area or stage of the mining operation, and on the handling of such hazardous materials during mining and reclamation according to previously developed plans.

Before issuing a permit to a coal or metal mining operation, the Oregon Department of Geology and Mineral Industries must find now that reclamation is possible and that the approved plan will achieve the reclamation of the affected lands. An operator who willfully abandons a site under these provisions shall not obtain another permit until he has reclaimed the abandoned site. The maximum bond or security authorized under these sections is $10,000 per acre of land to be surface mined, and the bond can be used by the Department to reclaim ground abandoned by an operator. The maximum fine for violation of rules and orders pursuant to the added sections of the law or for the operation of a coal or metal mine without a valid operating permit is $10,000.

RECLAMATION AWARD

At its April 9, 1981, meeting, the Department's Governing Board approved a proposal to recognize and honor an outstanding example of mined land reclamation each year. The award is intended to reward outstanding achievements by operators and to further the goal of reclamation by recognition and appropriate publicity. The first of these awards is to be announced in June 1982, and the Department and the Mined Land Reclamation Program welcome nominations from any source. This year's nomination deadline is April 15.

STATUS OF THE MLR PROGRAM

Total surface reclaimed (in acres):
1980: 106
1981: 326
1972 through 1981: 769

Total acreage under security to guarantee reclamation:
December 31, 1980: 2,173
December 31, 1981: 2,606

Uses to which acreage was reclaimed:

	Agriculture	Forestry	Housing	Other*
1972 through 1980:	251	6.5	37	148
During 1981:	168	7.0	21	129.5
Total	419	13.5	58	277.5

* "Other" includes water impoundments, sites for wildlife management, industrial-commercial sites, and permanent stockpiles.

New and closed sites, 1980 and 1981:
(Permits issued for new sites, records closed, sites reclaimed, or activity legally terminated)

	Surface mining permit[1]		Limited exemption[2]		Total exemption[3]	
	New	Closed	New	Closed	New	Closed
1980:	46	19	34	4	46	3
1981:[4]	84	32	50	7	51	26

[1] Sites requiring a fee, reclamation, and security.
[2] Sites requiring a fee, but legally exempt from reclamation and security.
[3] Sites legally exempt from fee, reclamation, and bonding.
[4] There were 71 other changes in status from one category to another during 1981.

Total number of sites under permit:

	Surface mining permit and limited exemption	Total exemption
As of December 31, 1980:	615	571
As of December 31, 1981:	703	587

Field inspections:
1980: 681
1981: 912 □

GSOC luncheon meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

March 19—*Native Clays and Glazes for North American Potters*: by Ralph Mason, geologist, retired.

April 2—*The Channeled Scablands of Eastern Washington: Geologic Story of the Spokane Flood:* by Donald D. Barr, naturalist and lecturer.

April 16—*Bella Colla and Beyond by Freighter:* by Phyllis and John Bonebrake, members and president of GSOC, 1975.

For additional information, contact Viola L. Oberson, Luncheon Chairwoman, phone (503) 282-3685. □

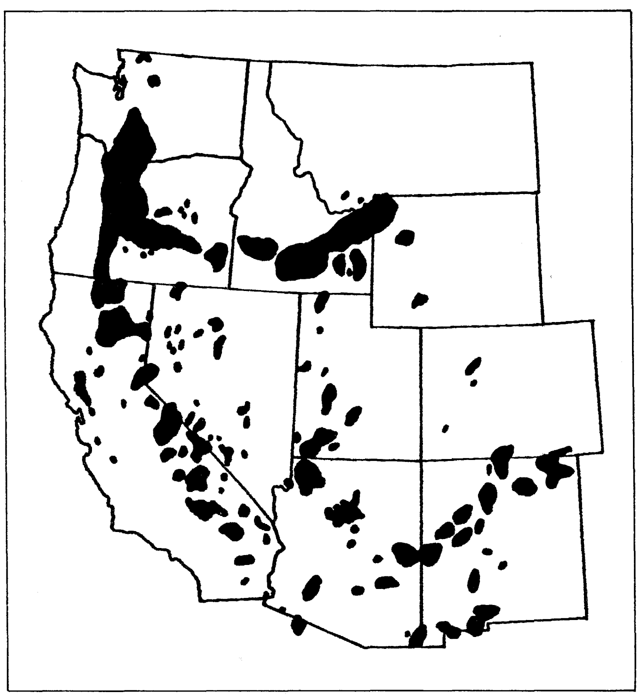
Western U.S. has at least 75 potentially active volcanic fields

In addition to about 15 volcanic centers in the Cascade Range and vicinity, there are at least 60 other identifiable volcanic centers in 11 western states which have the potential for future eruptions, U.S. Geological Survey (USGS) geologists Robert L. Smith and Robert G. Luedke announced at the December 1981 American Geophysical Union annual meeting in San Francisco.

Smith and Luedke described the results of a map compilation project designed to investigate potentially active volcanic zones and centers in the western United States, including Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The scientists say that they are not suggesting that an eruption from any of these volcanic fields is imminent, but that the probability for eruptions exists and therefore further studies are essential for adequate long-term land-use planning.

The distribution of volcanoes, volcanic fields, and volcanic rocks younger than 16 m.y. old in the western states suggests that (1) most of the volcanic activity has occurred along major linear zones, (2) any volcanic field that appeared during the last 5 m.y. may still be potentially active, and (3) new volcanic centers could form within the linear zones at any time.

The USGS spokesmen said that these conclusions are reinforced by the observation that many volcanic centers have demonstrated long life spans that have ranged from 1 to more than 10 m.y. The history of any volcanic field contains both major cycles of high activity and long cycles of no activity. The scientists noted that the timing of the intervals of volcanic activity can be characterized only in a very general way: for some volcanic centers the interval of dormancy may last 100 or 1,000 years; for others, 10,000 years; and for very large volcanic systems, 100,000 or even a million years may elapse between eruptions.



Dark areas show volcanic fields that have produced eruptions during the past 5 million years (m.y.) and that should be considered still potentially active, according to U.S. Geological Survey scientists. Map courtesy U.S. Geological Survey.

The USGS scientists concluded that further detailed studies of the volcanic centers are needed before scientists can truly understand volcanic processes and evaluate the probability of future eruptions of volcanic centers that have not erupted during the last 200 years. □

Annual Meeting of Geothermal Resources Council set for October in San Diego

The Geothermal Resources Council's (GRC) 1982 Annual Meeting will be held October 11-14, 1982, at the Sheraton Harbor Island Hotel in San Diego, California. There will be three days of technical sessions, along with poster sessions, special sessions, commercial and educational exhibits, a photo contest display, optional luncheons, special entertainment, and a guest program. In addition, both pre- and post-meeting field trips have been scheduled.

The meeting, which will officially begin with a reception on the evening of October 11, will feature a number of events for participants to choose from. A total of ten technical sessions is planned, at which formal oral presentations will be given. Special emphasis will be given to a separate poster session, and special sessions may be devoted to particular topics.

The Council's Annual Meeting is intended to provide a forum of exchange of new and significant information on the development and use of geothermal resources. Papers are solicited for both the technical and poster sessions on various aspects of geothermal energy and its development, including exploration, field development, applications, and politics-economics.

Authors may request that submitted papers be considered for oral presentation in the technical sessions, poster session presentation, or for publication only—or for a combination of the above. Deadline for submission of papers is Friday, June 4, 1982. Authors should consult with GRC for instructions.

For additional information about papers or the meeting, contact Geothermal Resources Council, P.O. Box 98, Davis, CA 95617, phone (916) 758-2360. □

Gryc appointed USGS Assistant Director, Western Region

George Gryc of Sunnyvale, Calif., a geologist widely recognized for his contributions to Alaskan geology, has been appointed Assistant Director for the Western Region, U.S. Geological Survey (USGS), Department of the Interior, at Regional Headquarters in Menlo Park, California.

Gryc has been acting in this capacity for the past several months while continuing his duties as chief of the Office of National Petroleum Reserve in Alaska (ONPRA). He has headed that office since 1977.

As Assistant Director, Gryc is the personal representative of the Director of the Geological Survey. He provides policy guidance, coordination of Survey activities, and liaison with federal, state, and local agencies in the states of Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington, as well as in the Pacific Trust Territories. □

OIL AND GAS NEWS

Mist Gas Field:

Drilling activity has resumed at the Mist Gas Field, where Reichhold Energy Corporation has drilled Columbia County 41-2 in sec. 2, T. 6 N., R. 5 W. The straight hole, drilled to 2,875 ft, was dry, and at last report, the 3,040-ft redrill was being logged.

Reichhold now plans to redrill Columbia County 12-9, which they drilled and suspended in 1980.

Clatsop County:

Diamond Shamrock holds much land under lease in Clatsop County and drilled three wells there last year (see article beginning on page 27, this issue). In 1982 the company plans to return to drill several more wells in the county. Locations have not yet been announced, but a June spud date is planned.

Douglas County:

An application from Florida Exploration Company to drill in sec. 4, T. 21 S., R. 6 W., has been the subject of two public hearings. At the second hearing, held February 18, 1982, in Roseburg, the Governing Board of the Oregon Department of Geology and Mineral Industries approved Florida's application. □

DOGAMI assessing mineral potential of wilderness study areas for BLM

The Oregon State Office of the Bureau of Land Management (BLM) has contracted with the Oregon Department of Geology and Mineral Industries (DOGAMI) to assess the mineral potential of approximately 800,000 acres of wilderness study areas in southeastern Oregon.

The $300,000 contract, which is to be completed by the spring of 1983, will include the assessment of the mineral potential of Steens Mountain, the Pueblo and Trout Creek Mountains, and Owyhee River areas, including the Honeycombs on the east side of the Owyhee River. The contract is the first phase of a three-phase proposal to inventory mineral potential of BLM's wilderness study areas in eastern Oregon.

BLM's Oregon State Director William G. Leavell commented, "This will add to our knowledge of energy and mineral potential in areas where this information is lacking. The results will contribute to intelligent wilderness study recommendations for BLM lands in Oregon."

Mineral potential is one of the many criteria BLM will use to determine whether or not areas will be recommended for wilderness designation. Suitability and non-suitability recommendations will be made to BLM's Director in Washington, D.C., and forwarded through the Secretary of the Interior to the President. The President will then make his recommendations to Congress. Only Congress can designate wilderness areas.

The contract calls for geological and geochemical surveys to identify areas with economic mineral potential. Samples will be analyzed for arsenic, barium, beryllium, cobalt, copper, gold, lead, manganese, mercury, molybdenum, nickel, silver, tin, tungsten, uranium, and zinc. Available information such as magnetic, geothermal, and gravity surveys will also be reviewed and integrated in the evaluation. □

Mineral deposits map of North America published by USGS

A map that shows more than 4,000 ore deposits of North America on a geologic background has been published by the U.S. Geological Survey (USGS). The 14-color map, titled *Preliminary Metallogenic Map of North America* (scale 1:5,000,000), depicts the geology and ore deposits from Greenland to Panama, including the islands of the Caribbean. It is 5×6 ft and printed in four sheets.

Colors and patterns on the map depict the rocks of North America and provide information on the amount of structural deformation, degree of metamorphism, chemical nature, and age of various units. The location, metal and mineral content, relative size, host-rock environment, igneous-rock association, type, and geologic age of 4,215 ore deposits and districts are shown on the map by colored symbols superimposed on the geology. Deposits of 26 metals that occur plus those of 15 of the more important nonmetallic minerals are distinguished on the map.

The map is the product of a cooperative effort by the geological surveys of the continent; the project was initiated in 1964 under the aegis of the Commission for the Geological Map of the World, an affiliate of the International Union of Geological Sciences.

Copies of the *Preliminary Metallogenic Map of North America* (four sheets) may be purchased for $10.00 a set from Branch of Distribution, U.S. Geological Survey, 1200 South Eads St., Arlington, VA 22202, or Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225. Orders must specify the map by name and include a check or money order payable to the U.S. Geological Survey. Copies of the companion reports, USGS Circular 858-A, *Preliminary Metallogenic Map of North America: A Numerical Listing of Deposits*, and USGS Circular 858-B, *An Alphabetical Listing of Deposits*, are free upon application to Text Products Section, Branch of Distribution, U.S. Geological Survey, 604 South Pickett St., Alexandria, VA 22304. □

Theme of PNMM conference to be "Discovery '82"

The Pacific Northwest Metals and Minerals Conference will hold its annual convention at the Sheraton Hotel in Spokane, Washington, on April 29 and 30 and May 1, 1982. The theme of the conference is "Discovery '82." The event is sponsored by the Pacific Northwest Sections of the American Institute of Mining, Metallurgical and Petroleum Engineers and by the American Society for Metals.

"Discovery '82" will explore new horizons, opportunities, and concepts for the mineral industry in 1982. Over 40 papers addressing the economics and geological setting of strategic minerals, the problems of shaft and small mining developments, the occurrence of precious metal deposits and the glamour of new discoveries, the changing governmental regulations facing the mining industry, and the advances in the aluminum casting technology will be presented.

For more information relating to the conference, please contact George Krempasky, Registration Chairman, U.S. Bureau of Mines, E. 360 Third Avenue, Spokane, WA 99202, phone (509) 456-5350. □

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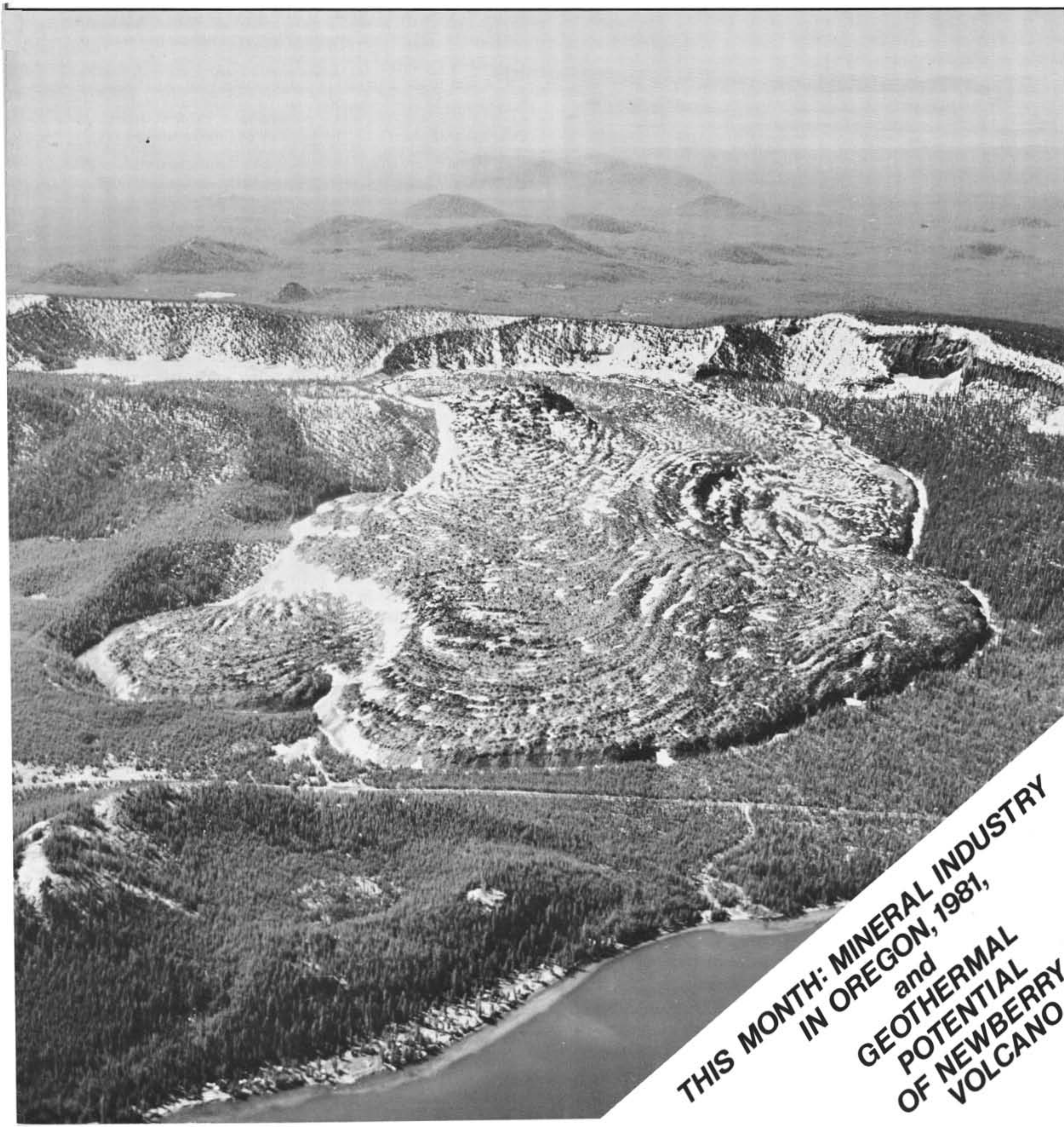

THIS MONTH: MINERAL INDUSTRY IN OREGON, 1981, and GEOTHERMAL POTENTIAL OF NEWBERRY VOLCANO

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COVER PHOTO

Looking to south at 1,400-year-old Big Obsidian Flow in caldera of Newberry Volcano. Article beginning on page 44 discusses geothermal potential of this large Quaternary volcano located southeast of Bend in central Oregon. Some data used in article came from U.S. Geological Survey drilling site to left (east) of Big Obsidian Flow. Several of more than 400 cinder cones that occur on flanks of volcano can be seen in background.

OIL AND GAS NEWS

Mist Gas Field:

Reichhold Energy Corporation continues to be the only active operator in the Mist Gas Field at present. The company recently finished the redrill of Columbia County 41-2 in sec. 2, T. 6 N., R. 5 W. The redrill, which reached a depth of 3,040 ft, was abandoned as a dry hole. Reichhold then moved the Taylor Drilling Company rig to Columbia County 12-9, a well drilled in 1980, and redrilled it to a depth of 2,917 ft. This redrill, too, was dry.

Columbia County:

About 10 mi southeast of production at Mist, Reichhold is rigging up to drill Columbia County 32-26. Located near the town of Pittsburg, this well is planned for 6,500 ft of depth. Depending on the results, the well may be followed by one or two others in the area.

State Lands lease sale:

On February 24 and 25, the Oregon Division of State Lands held an oil and gas lease auction in Portland. Over 75 people were present for bidding on 115,533 acres of state property in 15 counties. Bonus bids brought in over $590,000 on 212 of the 311 parcels offered; parcels without bids were awarded to the applicant for the annual rental fee of $1 per acre.

The highest bid was $215 per acre offered by Marathon for a 280-acre tract in Columbia County. Other acreage in Oregon's only gas-producing county went to Nahama and Weagant for $200 per acre.

Elsewhere in the state, bids were far lower. In Washington County, adjacent to Columbia County, several companies competed for acreage, with most of it going to Universal Resources for as high as $62 per acre. Other bidders included Conoco, Marathon, and Nahama and Weagant.

Central Oregon acreage was sought after by several bidders, including Anderson Oil Properties, Depco, EMEFCO, Shell Oil, Texaco, Tyrex, and Universal. Anderson was successful in leasing over 7,000 acres in Gilliam and Morrow Counties at offers averaging about $14 an acre. Depco leased all 13 parcels of submerged and submersible land under the Columbia River, Gilliam County.

Remaining acreage, mainly in Harney, Malheur, and Lake Counties, was awarded to the applicant or went for bids of only a few dollars an acre. Garth Tallman, Jerry Ryan, Inca Oil and Gas, and Anschutz Corporation took most of the acreage in these counties for no bid.

Lease sale results may be obtained from the Division of State Lands, 1445 State Street, Salem, Oregon 97310, phone (503) 378-3805.

Northwest Association of Petroleum Landmen organize:

After the lease sale discussed above, about 25 landmen, consultants, and attorneys gathered to form a Northwest Association of Petroleum Landmen for Oregon, Washington, and Idaho. They will try to affiliate with the nationwide American Association of Petroleum Landmen. A temporary committee was formed to organize the group. □

CONTENTS

Mineral industry in Oregon, 1981

by Len Ramp, Resident Geologist, Grants Pass Field Office; Howard C. Brooks, Resident Geologist, Baker Field Office; and Jerry J. Gray, Economic Geologist, Albany Field Office, Oregon Department of Geology and Mineral Industries

INTRODUCTION

The total value of Oregon's 1981 mineral production (preliminary U.S. Bureau of Mines figures, revised; see Table 1) is down about five percent from 1980 figures in spite of increased nickel production by the Hanna Mining Company's nickel mine and smelter at Nickel Mountain near Riddle. Production of most industrial minerals, especially sand and gravel, dropped in 1981 due to the depressed construction industry. Gold production was also down somewhat below the 1980 figure, which had been boosted by production from the Applegate Dam project; furthermore, total value of gold production was significantly affected by the drop in gold price in 1981.

Estimated total gold production figures for 1980 and 1981 (Table 1) were derived by canvassing a number of individual producers. Table 1 also includes some additional estimated production figures from numerous small part-time placer operators. An average value of $600 per ounce was used for the 1980 figure and $475 for 1981. (These figures were obtained by using the Handy and Harmon, New York, monthly price average in *Engineering and Mining Journal.*)

METALS

Gold placer mining continued at several sites during 1981. Veta Grande Corporation purchased the Mormon Basin and Basin Creek Placer Mines about 30 mi southeast of Baker. Both mines were active producers during 1980 and 1981 (Mine 10*). The Sucker Creek Gallagher Placer (Mine 4), which also changed ownership during the year, was purchased by Oscar Nukka. Gold production came from these and many other small placer operations, from a few small lode mines, and, as a major by-product, from the Iron Dyke Mine (Mine 8).

Table 1. *Nonfuel mineral production in Oregon, 1980 and 1981*

Mineral	1980 Quantity	1980 Value ($1,000)	1981[1] Quantity	1981[1] Value ($1,000)
Clays (1,000 short tons)	172	321	80	155
Gem stones	NA	450	NA	500
Gold—recoverable content of ores, etc. (troy oz)[2]	14,268	8,561	10,405	4,942
Nickel—content of ores and concentrates (short tons)	14,653	W	15,608	W
Pumice (1,000 short tons)	1,090	2,734	965	2,600
Sand and gravel (1,000 short tons)	16,005	47,300	14,800	44,200
Silver—recoverable content of ores, etc. (troy oz)	1,000	17	W	W
Stone:				
Crushed (1,000 short tons)	18,380	48,190	15,100	40,900
Dimension (1,000 short tons)	15	231	15	247
Combined value of cement, diatomite, lime, talc, and values indicated above by symbol W	XX	50,364	XX	56,480
Total	XX	158,168	XX	150,024

[1] 1980 and preliminary 1981 data provided by U.S. Bureau of Mines. Production as measured by mine shipments, sales, or marketable production (including consumption by producers). NA = Not available. W = Withheld to avoid disclosing company proprietary data; value included in "Combined value" figure. XX = Not applicable.

[2] Oregon Department of Geology and Mineral Industries canvass; includes estimates of unreported production.

Gold dredges in Illinois River just downstream from McCaleb Ranch, Josephine County.

Mining at the Iron Dyke Mine in eastern Oregon continued during the year, with 40 employees producing about 75 tons per day of sulfide ore bearing gold, silver, and copper. The ore is hauled about 22 mi across the Snake River and up the Kleinschmidt Grade to the Silver King Mill at Cuprum, Idaho.

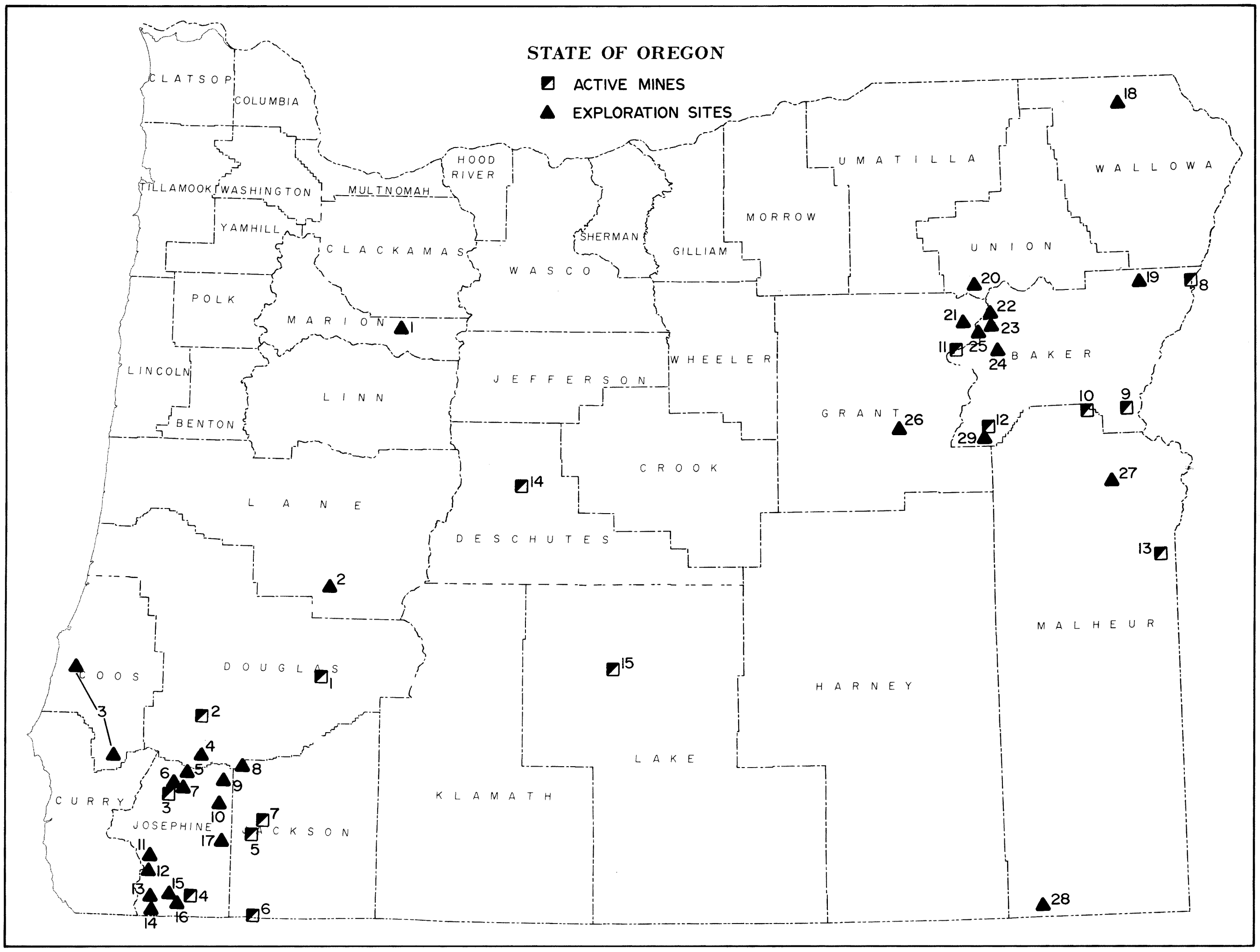
In southwestern Oregon, the Hanna Mining Company's nickel mine and smelter at Nickel Mountain (Mine 2) continued production as the sole domestic source of nickel. The mine currently operates at the per-shift rate of 2,000 short tons of ore containing 0.87 percent nickel which is upgraded by selective screening to provide a smelter-feed content of 0.97 percent. The smelter produces ferronickel containing 51-54 percent nickel. During the first few years of operation, which began in 1954, the initial grade of smelter feed was 1.5 percent nickel. Depletion of higher grade saprolitic and silica-boxwork ore in the main orebody and increased use of ore from the satellite landslide orebodies has resulted in a steady decline in grade during recent years.

The Old Channel Placer Mine (Mine 3) near Galice was reactivated during the year by Wes Pieren. In this operation, bed rock and minor remnant gravels are ripped up, using a bulldozer, loader, and trucks, and run through a sluice. Water for the sluice is recycled from a settling pond with a large diesel-powered pump.

METAL PROCESSING

Oregon's metallurgical industry grew during 1981 with the expansion of Oremet's titanium plant in Albany and with con-

* All mine numbers refer to "Active Mines" on location map and in Table 2.



EXPLANATION

ACTIVE MINES

1. Quartz Mountain Silica
2. Nickel Mountain (Ni)
3. Old Channel Placer (Au)
4. Sucker Creek Placer (Au)
5. Bristol Silica (dolomite)
6. Steatite of Oregon (soapstone)
7. Sylvanite-Lyman (Au)
8. Iron Dyke (Au, Ag, Cu)
9. Oregon Portland Cement (limestone)
10. Mormon Basin Placer (Au)
11. Pyx (Au)
12. Thomason (Au)
13. Adrian (bentonite, zeolite)
14. Cascade Pumice, Central Oregon Pumice
15. Christmas Valley (diatomite)

EXPLORATION SITES AND AREAS

1. North Santiam area (Cu, Zn, Au, Ag)
2. Bohemia district (Cu, Zn, Au, Ag)
3. Coos County coal deposits
4. McCullough Creek area (Cu, Zn, Ag)
5. Goff Prospect (Au, Ag, Cu, barite)
6. Yankee Silver Mine (Au, Ag)
7. Almeda Mine (Au, Ag, Cu, barite)
8. Warner Mine (Au)
9. Yellowhorn Mine (Au)
10. Oak Mine (Au, Cu)
11. Fall Creek Prospect (Cu)
12. Lightning Gulch Group (Au, Ag, Cu)
13. Nickel laterite deposits (Ni, Cr, Co)
14. Turner-Albright Mine (Cu, Au, Co)
15. Esterly Placer area (Au)
16. Queen of Bronze Mine (Cu, Au)
17. Iron Hat Prospect (Cu, Au)
18. Flora coal deposits (lignite)
19. Cornucopia Mine (Au, Ag)
20. Camp Carson Placer (Au)
21. Cougar Mine (Au, Ag)
22. Argonaut Mine (Au, Ag)
23. North Pole, E and E, Columbia Mines (Au, Ag)
24. Sumpter Valley Placer (Au)
25. Bald Mountain, Ibex Mines (Au, Ag)
26. Chambers Mine (Canyon Mountain area) (Cr)
27. Hope Butte (Au)
28. Trout Creek Mountains (U)
29. Grouse Spring Prospect (Cu, Mo)

Mineral industry activity, exploration, and development in Oregon in 1981. Mine and site numbers in text refer to location numbers shown on this map.

Table 2. *Active mines in Oregon, 1981*

Map no.	Name	Location	Comments
1.	Quartz Mountain Silica	Sec. 2 T. 28 S., R. 1 E. Douglas County	Production of 10,000 tons this year.
2.	Nickel Mountain	Sec. 17 T. 30 S., R. 6 W. Douglas County	Continuing production at mine and smelter.
3.	Old Channel Placer	Sec. 35 T. 34 S., R. 8 W. Josephine County	Operator Wes Pieren. Gold production from ripped-up bed rock.
4.	Sucker Creek Placer	Sec. 1 T. 40 S., R. 7 W. Josephine County	Gallagher's washing plant.
5.	Bristol Silica	Sec. 30 T. 36 S., R. 3 W. Jackson County	Produced some dolomite.
6.	Steatite of Southern Oregon	Secs. 10, 11 T. 41 S., R. 3 W. Jackson County	Block soapstone for carving. Production small but increasing.
7.	Sylvanite-Lyman	Sec. 2 T. 36 S., R. 3 W. Jackson County	Small-scale mining of high-grade ore from old workings.
8.	Iron Dyke	Sec. 21 T. 6 S., R. 48 E. Baker County	Owner Texas Gulf, operator Silver King. Massive sulfide ore contains Au, Ag, Cu. Mine employs 40 on five-day basis.
9.	Oregon Portland Cement	Sec. 11 T. 12 S., R. 43 E. Baker County	Continuing operation of new 500,000-ton coal-fired plant.
10.	Mormon Basin Placer	Sec. 21 T. 13 S., R. 42 E. Malheur County	Dragline and washing plant reported production of 10-20 oz of gold per day. Mine was purchased by Vita Grande Corp.
11.	Pyx	Secs. 1, 2 T. 10 S., R. 35 E. Baker County	Small gold production; four employed.
12.	Thomason	Secs. 6, 7 T. 14 S., R. 37 E. Baker County	Unity area. Operator, Art Cheatham. Gold in serpentine shear zone. 1-ton/hr mill, three employed.
13.	Adrian	Sec. 29 T. 23 S., R. 46 E. Malheur County	Teague Mineral Products drying and bagging plant. Small production.
14.	Cascade Pumice, Central Oregon Pumice	Bend area Deschutes County	Continuing operation with increase in annual production.
15.	Christmas Valley	– T. 27 S., R. 17 E. Lake County	Oil-Dri West continuing production for pet litter and floor sweep.

struction at St. Helens, Oregon, of Bergsoe Metal's new 50,000-tons-per-year smelter designed to recover lead from old batteries. Albany Titanium, Inc., announced plans to install a new titanium sponge plant in Albany.

On the negative side were the Reynolds Metals' shutdown of two 25,000-tons-per-year potlines at its Troutdale aluminum plant and Union Carbide's plans to close its Portland ferroalloy plant.

NONMETALS

Oregon's Economic Development Commission approved $1.9 million in industrial development bonds for North Santiam Sand and Gravel, Inc., to expand its cement plant in Marion County and construct an asphalt plant in Linn County. The Portland City Council granted a 35-year conditional-use permit for gravel mining on Ross Island to Ross Island Sand and Gravel Company.

Teague Mineral Products produces bentonite and zeolite for various uses. Production has expanded at the company's drying, grinding, and bagging plant (Mine 13) near Adrian in Malheur County. Zeolite is marketed as a livestock food additive for poultry and hogs.

The Quartz Mountain Silica Mine in Douglas County (Mine 1) saw production reduced to about 10,000 tons during the year, due in part to a 250-percent increase in road-maintenance charges from $1.23 to $4.37 per ton by the U.S. Forest Service. In the past, the mine has usually produced 20,000-25,000 tons per year of quartz that is hauled over 26.4 mi of Forest Service roads on the 75-mi trip to the Hanna nickel smelter. The quartz is smelted with scrap iron to make ferrosilicon which is used in the nickel-reduction process at the smelter near Riddle.

EXPLORATION AND DEVELOPMENT ACTIVITY

Coal

During 1981, considerable interest was shown in coal deposits. Coos County subbituminous deposits (Site 3**) have received much attention, and several companies, including Bear Creek, AMAX, Canasia, and GCO Minerals, have been actively involved in exploration, reconnaissance mapping, and leasing. AMAX conducted a drilling program near Riverton. At year's end, Coos County signed a lease agreement for 4,000 acres with GCO Minerals Company.

A large deposit of low-grade lignite coal 20-40 ft thick in the vicinity of Flora (Site 18), northern Wallowa County, has been explored by Utah International. The company's application to the Wallowa County Planning Commission for a conditional-use permit to excavate a bulk sample of coal was withdrawn last summer, in part due to local ranchers' opposition to strip mining. Further work is reportedly planned by Utah International, which has requested a new conditional-use permit for a sample pit about 5 mi northwest of Flora.

Base metals and precious metals

Interest in exploring for volcanogenic sulfide deposits continued during 1981. An article by Koski and Derkey (*Oregon Geology*, v. 43, no. 9, p. 119-125) describes the genesis of volcanogenic sulfide deposits in southwestern Oregon, where much of the exploration activity has been centered. Mineral deposits along the "Big Yank Lode" mineralized zone, including those of the Silver Peak Mine in Douglas County and the Almeda Mine in Josephine County, are described by Koski and Derkey as island-arc volcanogenic deposits. Exxon is exploring a segment of this zone along McCullough Creek (Site 4), a short distance northeast of Glendale. Other segments under exploration are the Goff Prospect (Site 5), by American Selco; the Almeda Mine (Site 7), by Comanche and Blue Diamond; and the Yankee Silver Mine (Site 6), by owner George Reynolds.

One of the apparently successful exploration programs in southwestern Oregon is the work done by Baretta Mining at the Turner-Albright Mine (Site 14), where sufficient low-grade copper-, zinc-, and gold-bearing sulfide ore has reportedly been blocked out to justify a mining operation. The ore occurs

** All site numbers refer to "Exploration Sites and Areas" on location map and in Table 3.

Table 3. *Exploration sites and areas in Oregon, 1981*

Map no.	Site or area name	Location	Comments
1.	North Santiam area:	Marion County	
	Ruth Mine	Sec. 27 T. 8 S., R. 5 W.	AMOCO drilling and exploring surrounding area of sulfide mineralization in Western Cascades volcanic rocks.
2.	Bohemia district:	Lane County	
	a. Champion and Helena Mines	Secs. 7, 8, 12, 13 T 23 S.; Rs. 1, 2 E.	Hanuman (Galactic Resources, Ltd.) mapping and sampling. Reopened workings, surface and underground; plan to drill.
	b. President Mine (El Capitain)	Sec. 23 T. 23 S., R. 1 E.	Local group plans to build mill.
	c. North Fairview, Lead Crystal, Elephant II, Lizzie Mines	Secs. 2, 11 T. 23 S., R. 1 E.	Guy Leabo and associates constructing small mill for both free milling and complex ore.
3.	Coos County coal deposits	Coos Bay and Eden Ridge, Coos County	Several companies, Bear Creek, AMAX, Canasia, and GCO, involved in exploration, leasing, mapping, and some drilling.
4.	McCullough Creek area	Sec. 30 T. 32 S., R. 6 W. Douglas County	Exxon has done geophysical work, leasing, surface mapping, sampling, and drilling in sulfide-mineralized zone.
5.	Goff Prospect	Sec. 29 T. 33 S., R. 7 W. Josephine County	American Selco drilling segment of Big Yank Lode in area with barite and abundant sulfides.
6.	Yankee Silver Mine	Secs. 25, 26 T. 34 S., R. 8 W. Josephine County	Owner George Reynolds prospecting siliceous gold ore.
7.	Almeda Mine	Sec. 13 T. 34 S., R. 8 W. Josephine County	Comanche Petroleum and Blue Diamond Energy Resources have optioned property, located claims, and done geophysical survey. Hope to develop Au, Ag, and barite ores.
8.	Warner Mine	Sec. 4 T. 33 S., R. 4 W. Jackson County	Galactic Resources opened workings, mapped, and sampled. Plan to drill geophysical anomaly for gold.
9.	Yellowhorn Mine	Sec. 5 T. 33 S., R. 5 W. Josephine County	John Miller reopening mine and building small mill. Three men employed.
10.	Oak Mine	Sec. 4 T. 35 S., R. 5 W. Josephine County	Dennison has conducted geophysical survey and plans to drill anomalies in massive sulfide zone.
11.	Fall Creek Prospect	Sec. 4 T. 38 S., R. 9 W. Josephine County	Mining Enterprises of Arnold, California, has conducted geophysical survey and plans to drill copper prospect.
12.	Lightning Gulch Group	— Tps. 38, 39 S.; R. 9 W. Josephine County	FMC, Inc., conducting geophysical and geochemical surveys, claim staking, and mapping over extensive area.
13.	Nickel laterite deposits	Southwest Oregon	Inspiration Development, U.S. Nickel, and Hanna Mining holding claims and doing assessment work to extend reserves of Ni, Cr, Co in the Josephine ultramafic sheet and other southwest Oregon areas.
14.	Turner-Albright Mine	Secs. 15, 16 T. 41 S., R. 9 W. Josephine County	Baretta Mining recently completed extensive drilling, mapping, and sampling program for Cu, Au, Co.
15.	Esterly Placer area	Sec. 22 T. 40 S., R. 8 W. Josephine County	Cal Nickel exploring, with tentative plans to set up gold mining operation.
16.	Queen of Bronze Mine	Sec. 36 T. 40 S., R. 8 W. Josephine County	Dennison continued mapping and sampling underground plus surface geophysical work for Cu, Au.

Table 3. *Exploration sites and areas in Oregon, 1981—continued*

Map no.	Site or area name	Location	Comments
17.	Iron Hat Prospect	Sec. 17 T. 37 S., R. 5 W. Josephine County	Associated Geologists plan to drill electromagnetic anomaly for Cu, Au.
18.	Flora coal deposits	Northern Wallowa County	Utah International mapping, leasing, and drilling lignite deposit up to 40 ft thick.
19.	Cornucopia Mine	Secs. 27, 28 T. 6 S., R. 45 E. Baker County	United Nuclear Mining and Milling Services, Inc., reopening old gold mine. Plan extensive exploration and testing. Rehabilitated old Coulter adit at 2,000-ft level.
20.	Camp Carson Placer	Sec. 28 T. 6 S., R. 36 E. Union County	Local group has moved in equipment to reactivate gold placer mine.
21.	Cougar Mine	Sec. 27 T. 8 S., R. 35½ E. Grant County	W.A. Bowes and Associates exploring old gold mine last five years. Operations cut back late in 1981.
22.	Argonaut Mine	Sec. 19 T. 8 S., R. 37 E. Baker County	Baker Mines, Ltd., (Norvan, Ltd.), reopening, sampling, and extending old workings for Au.
23.	North Pole, E and E, and Columbia Mines	Sec. 32 T. 8 S., R. 37 E. Baker County	Brooks Minerals and AMAX driving 3,800-ft adit 400 ft below creek level on North Pole-Columbia Lode, 10-300 ft wide and 4.5 mi long, in argillite. Employing average of 30 people. Prior production from lode reported to be about $9 million.
24.	Sumpter Valley Placer	— T. 10 S.; Rs. 37, 38 E. Baker County	Noranda has submitted applications for drilling permits and land acquisition; may redredge.
25.	Bald Mountain and Ibex Mines	Sec. 3 T. 9 S., R. 36 E. Baker and Grant Counties	NERCO, Inc., (Pacific Power and Light) reopening old workings and sampling quartz-calcite vein (5-25 ft wide) in argillite.
26.	Chambers Mine (Canyon Mountain area)	Sec. 13 T. 14 S., R. 32 E. Grant County	American Chrome (Baretta) did some drilling of chromite deposits.
27.	Hope Butte	Sec. 21 T. 17 S., R. 43 E. Malheur County	Homestake Mining exploring area of old Jordan quicksilver prospect for gold in opalized tuffs and rhyolite flows with interbedded lake sediments. Work was begun in 1979 and is continuing.
28.	Trout Creek Mountains	— Tps. 40, 41 S.; Rs. 38, 39 E. Malheur County	Anaconda, Placer Amex, and other major companies continuing exploration for uranium in Miocene ash-flow tuffs and lake sediments of McDermitt Caldera.
29.	Grouse Spring Prospect	Secs. 24, 25 T. 14 S., R. 36 E. Baker County	Johns Manville exploring for Cu, Mo. Did some drilling for assessment work.

in the Josephine ophiolite overlying a sheeted diabase dike complex.

There has been widespread exploration activity in eastern Oregon. Gold-bearing veins in the Cracker Creek area of western Baker County appear to have been the scene of greatest activity. Work to reopen the old E and E and North Pole Mines on the North Pole-Columbia Lode (Site 23) and the Bald Mountain and Ibex Mines (Site 25) continued throughout 1981.

Considerable interest has also been shown in Oregon's epithermal opalized areas and associated quicksilver deposits because large deposits of gold have been found in similar areas in California. Exploration by Homestake at Hope Butte (Site 27) in northern Malheur County is the result of this interest.

Little actual exploration work has been done on chromite deposits in the state, except for American Chrome's brief drilling program on Canyon Mountain (Site 26) near John Day. Industry recognizes the very strategic nature of chromite and is looking into domestic deposits with renewed interest. Nearly all of the known chromite deposits in southwestern Oregon have been investigated, and new mining claims have been located.

Exploration and development on nickel-bearing laterite deposits (Site 13), especially in the Josephine ultramafic sheet, have continued at a somewhat reduced pace. All existing claims are being kept current, and the type of assessment work currently being done generally involves drilling, sampling, and other types of exploration to prove up additional reserves. Nomination of the east side of Eight Dollar Mountain as a Bureau of Land Management Area of Critical Environmental Concern (ACEC) may affect future development of the laterite deposits in that area. □

An estimate of the geothermal potential of Newberry Volcano, Oregon

by Gerald L. Black, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Newberry Volcano is a large Quaternary volcano located in central Oregon about 32 km (20 mi) southeast of Bend (Figure 1). It covers an area of nearly 1,300 km² (500 mi²) and, according to MacLeod and others (1981), consists of "basalt and basaltic andesite flows, andesitic to rhyolitic ash-flow and air-fall tuffs and other types of pyroclastic deposits, dacite to rhyolite domes and flows, and alluvial sediments produced during periods of erosion." More than 400 cinder cones dot the flanks of the volcano. The most recent activity occurred approximately 1,400 years ago in the summit caldera and resulted in the formation of the Big Obsidian Flow. The volcano is considered dormant but capable of future eruptions (MacLeod and others, 1981).

During the summer of 1981, the Geothermal Research Program of the U.S. Geological Survey (USGS) completed drilling a 930-m (3,051-ft) test hole (Newberry 2) in the summit caldera of Newberry Volcano. Fluids at a temperature of 265° C (509° F) were encountered in permeable rocks in the bottom 1.8 m (6 ft) of the hole (Sammel, 1981).

The intent of this paper is to provide a general update of the estimated geothermal electrical generation potential of the volcano, based on refinements in the estimates of reservoir temperature and volume. The temperature refinements are based on considerations of the relative validity of various methods of geothermometry and on data obtained from the USGS drill hole. The volume refinements are based on USGS drill-hole data and on gravity modeling recently completed in the area by the USGS (Williams and Finn, 1981).

PREVIOUS RESERVOIR ESTIMATES

In USGS Circular 790, Brook and others (1979) estimate the mean reservoir thermal energy of Newberry to be $27 \pm 10 \times 10^{18}$ J (joules), resulting in a theoretical electrical generation potential of 740 MWe (megawatts electric). These estimates are based upon a mean reservoir temperature of 230° ± 20° C and a mean reservoir volume of 47 ± 16 km³.

GEOTHERMOMETRY

Normally, chemical geothermometers are used to estimate the reservoir temperatures of geothermal systems. These temperature-dependent water-rock reactions, however, are valid only for hot-water systems, as the chemical constituents used in the calculations (Na, K, Ca, Mg, SiO_2, Cl) are not soluble in steam (White, 1973). Although there are two hot springs in the summit caldera of Newberry Volcano (East Lake and Paulina Hot Springs), their chemistry is not considered a reliable indicator of reservoir temperature. Both springs issue from lapilli tuffs along the shores of lakes occupying the caldera floor and are characterized by low flow rates and high silica concentrations. Mariner and others (1980) believe that (1) the springs are probably drowned volcanic gas vents, and (2) the solution of glass from the lapilli tuffs could account for observed high silica and magnesium concentrations which, in turn, would be a function of the length of time that heated lake waters were in contact with the tuffs. A warm well located in Little Crater Campground (between East and Paulina Lakes) probably suffers from the same limitations.

Because of the uncertainty surrounding the geothermometers derived from the chemistry of East Lake and Paulina Hot Springs, Brook and others (1979) infer a reservoir temperature of 230° ± 20° C, based on temperatures estimated for other Quaternary volcanoes. Since results of the Newberry 2 test hole (Figure 2) indicate a minimum temperature of 265° C at the top of the reservoir, the problem becomes one of estimating maximum and mean reservoir temperatures. One possible solution is to use the chemical geothermometers while keeping in mind their limitations. Unfortunately, the Na-K, Na-K-Ca, and SiO_2 geothermometers all indicate minimum reservoir

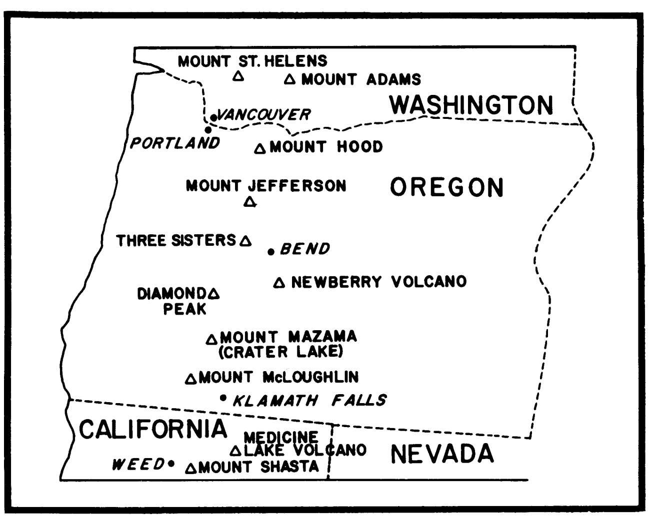


Figure 1. Map showing locations of some major volcanoes in the High Cascades Range of Washington, Oregon, and California. Taken from Sammel (1981).

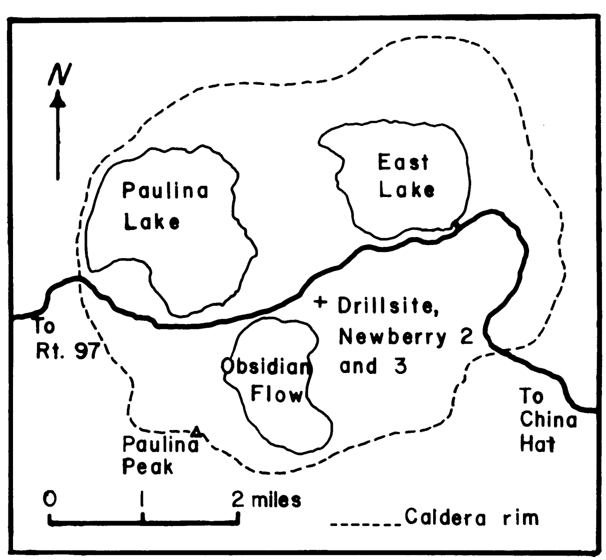


Figure 2. Map of Newberry Caldera, showing the Newberry 2 test site. Taken from Sammel (1981).

temperatures of less than 200° C (Mariner and others, 1980). A new method based on the Na/Li ratio (Fouillac and Michard, 1981) gives reservoir temperatures of 335° C, 375° C, and 370° C for East Lake Hot Springs, Paulina Hot Springs, and the Little Crater Campground warm well, respectively (based on analyses from Mariner and others, 1980).

The reliability of the Na/Li geothermometer is difficult to assess. In general, higher temperatures correspond to lower Na/Li ratios. If, however, the concentration of sodium in the thermal water is a function not only of temperature but also of the length of time that the water has been in contact with lapilli tuffs (Mariner and others, 1980), then the result is a higher Na/Li ratio and a lower estimated reservoir temperature. This implies that the calculated temperatures are minimums, assuming, of course, that the concentration of lithium in the thermal water is a function of subsurface temperature and is not affected by the length of time the water is in contact with the tuffs. This may indeed be the case. According to Fouillac and Michard (1981), the concentration of lithium in thermal waters increases with increasing temperature, varying over about four orders of magnitude between 0° and 300° C. They feel that it is unlikely that the concentration of lithium in thermal waters is due to chemical equilibrium between water and a lithium mineral, and they believe that water-rock ratios and rock type do not affect lithium concentrations. Given these findings, it is possible that the temperatures resulting from Na/Li ratios give useful indications of minimum reservoir temperatures beneath the caldera at Newberry Volcano. Even if Paulina and East Lake Hot Springs are drowned fumaroles, the Na/Li ratios should be characteristic of the temperature of the thermal fluid at the point of mixing. Since the temperature of the mixture is presumably less than the temperature at depth, the resulting Na/Li geothermometer should give useful minimum reservoir temperatures.

Based on the above considerations, a maximum reservoir temperature of 360° C and a mean reservoir temperature of 312.5° C have been selected for use in the calculations of geothermal potential. The maximum is simply the mean of the three Na/Li geothermometers (335° C, 375° C, and 370° C) discussed above, while the mean reservoir temperature is the arithmetic average of the maximum (360° C) and the temperature encountered at the bottom of the Newberry 2 test hole (265° C). These temperatures are higher than those encountered in many producing geothermal fields around the world, but they are not unheard of. The Cerro Prieto field in the Mexicali district of Mexico, for example, produces fluids at temperatures of 310° to 350° C from depths of 1,700-2,000 m (Espinosa, 1982).

RESERVOIR VOLUME

Brook and others (1979) assume a reservoir volume of 47 ± 16 km³ in their estimation of the geothermal potential of Newberry Volcano. This estimate is based upon a caldera area of 32 km² and a minimum, maximum, and most likely depth to the top of the reservoir of 0.5, 2.0, and 1.5 km, respectively. They chose these numbers because the depths to the tops of the reservoirs in most drilled geothermal systems fall within that range and because at the time of their study there were no drill hole data available from Newberry indicating the true top of the reservoir. Assuming a maximum drillable depth of 3 km for the reservoir bottom, Brook and others (1979) calculate a maximum reservoir thickness of 2.5 km, a minimum of 1.0 km, and a most likely thickness of 1.5 km. The results from Newberry 2 indicate a depth to the top of the reservoir of 0.93 km (Sammel, 1981) and thus a calculated reservoir thickness of 2.07 km, the value that is used in this paper in calculating reservoir thermal energy. An important assumption used in the calculation of reservoir volumes is that all portions of the reservoir are considered to be equally porous and permeable; no attempt is made to separate those portions of the reservoir which are porous and permeable from those which are not (Brook and others, 1979).

Williams and Finn (1981), in a reexamination of gravity data from Newberry, delineate a large positive residual gravity anomaly associated with the volcano. The anomaly extends well outside the margins of the volcano, covers an area of approximately 275 km² (D.L. Williams, 1982, personal communication), and is interpreted by Williams and Finn (1981) to be a subvolcanic intrusive. The top of the intrusive lies at a depth of less than 2 km (D.L. Williams, 1982, personal communication) and is probably composed of a complex of many separate intrusions in different states of cooling (Williams and Finn, 1981). While it is highly unlikely that temperatures similar to those encountered in the Newberry 2 test hole underlie the entire area of the positive gravity anomaly, calculations will be made using that assumption in order to arrive at an upper limit for the electrical generation potential of the volcano.

ELECTRICAL POWER CALCULATIONS

The techniques developed by Brook and others (1979) for estimating the electrical generation potential of a geothermal area are relatively straightforward, once reasonable estimates of reservoir temperatures and volumes have been made. As a first step, the accessible resource base (the stored heat of the system above 15° C and shallower than 3 km) is calculated, using the formula:

$$q_R = pc \cdot a \cdot d \cdot (t - t_{ref}),$$

where q_R is the reservoir thermal energy in joules (J), pc is the volumetric specific heat of rock plus water (2.7 J/cm³/° C), a is the reservoir area in km², d is the reservoir thickness in km, t is the reservoir temperature, and t_{ref} is the reference temperature (15° C). The value for pc assumes a reservoir porosity of 15 percent and t_{ref} is the mean annual surface temperature, which for simplicity is assumed to be constant throughout the United States.

Once the reservoir thermal energy (q_R) has been calculated, the problem becomes one of determining how much of that energy can be turned into electricity. To generate electricity, the thermal energy of the reservoir is converted into mechanical energy (work), which in turn is converted to electrical energy. The mechanical work available (W_A) at the wellhead can be determined from a graph conveniently provided in USGS Circular 790 (Brook and others, 1979). For a reservoir temperature of 312.5° C and a depth to the center of the reservoir of 2 km, the ratio W_A/q_R is equal to 0.082 ($W_A/q_R = 0.082$). Hidden within this simple computation are the following important assumptions which are discussed in more detail by Brook and others (1979): (1) In an ideal reservoir, 50 percent of the reservoir thermal energy can be recovered at the wellhead; (2) nonideal reservoir conditions, mostly related to the fact that much of the reservoir volume is not porous and permeable, limit wellhead recoverability to 25 percent of the reservoir thermal energy; and (3) the condenser rejection temperature is 15° C. This last assumption tends to maximize the available work (W_A) term, as the true condenser rejection temperature will usually be higher, around 40° C.

The electrical energy obtainable from a geothermal system is calculated from the equation:

$$E = W_A \cdot \eta_u,$$

where η_u is a utilization factor that accounts for losses that occur in the power cycle (Brook and others, 1979). The value of η_u is simply the ratio of actual work to available work (W_A) for a given system. A value of 0.4 was chosen by Brook and others (1979) as typical of hot water systems and is used in this paper. It should be noted that the calculation of actual work (used in determining η_u) assumes a condenser rejection temperature of 40° C.

Table 1 lists the results of the various calculations made for Newberry Volcano. The values for electrical energy are given in electrical megawatts based on a 30-year life span.

Table 1. *Estimates of volume, temperature, and energies of Newberry Volcano*

Source of calculation	Reservoir volume (km^3)	Reservoir temperature (° C)	Reservoir thermal energy (10^{18} J)	Electrical (MWe for 30 years)
USGS Circ. 790[1]	47±16	230±20	27±10	740
DOGAMI[2]	47	312.5	38	1,316
DOGAMI[3]	66	312.5	53	1,843
DOGAMI[4]	569	312.5	457	15,837

[1] Brook and others, 1979, p. 54.

[2] Oregon Department of Geology and Mineral Industries (DOGAMI) calculation, using reservoir volume estimate of Brook and others (1979) and new temperature data from Newberry 2 test well.

[3] DOGAMI calculation using increases in both reservoir temperature and volume from Newberry 2 hole (Sammel, 1981).

[4] DOGAMI calculation using volume estimate based on gravity work of Williams and Finn (1981).

Two things are immediately obvious from the information contained in Table 1. First, the new data from the Newberry 2 test well more than double the theoretical electrical generation potential of the caldera portion of the Newberry Volcano; and second, there may be enormous potential outside the caldera proper. The 15,837-MWe estimate for the entire gravity anomaly associated with the volcano is, of course, an absolute maximum. It is based on the assumptions that (1) the intrusive causing the gravity anomaly is everywhere providing heat at the rate found in the Newberry 2 test hole, and (2) the reservoir is everywhere 2.07 km thick (i.e., the top of the reservoir lies everywhere at a depth of approximately 1 km). While these assumptions are certainly not completely valid, they provide a useful upper limit on the potential of the volcano. The extent to which they are in error and the true geothermal potential of the volcano can be determined only by exploratory drilling.

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MEETING ANNOUNCEMENTS

GSOC luncheon meetings

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

April 16—*Bella Coola by Freighter and Beyond*: by Phyllis and John Bonebrake, members and president of GSOC, 1975.

May 7—*The Columbia River Gorge: Who Is Watching?* by Nancy Russell, lecturer on Oregon native plants and chairwoman of Friends of the Columbia Gorge.

May 21—*Forty Floods*: by John Eliot Allen, Emeritus Professor of Geology, Portland State University.

For additional information, contact Viola L. Oberson, Luncheon Chairwoman, phone (503) 282-3685.

AIME dinner meeting

The monthly dinner meeting of the Oregon section of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) will be held Friday evening, April 16, at the Flamingo Best Western Motel and Restaurant, 9727 NE Sandy Boulevard in Portland. The speaker will be Herbert H. Kellogg, 1982 Henry Krumb Lecturer and Professor of Metallurgy at the Henry Krumb School of Mines at Columbia University, who will speak on *Energy Use in Metal Production*.

Cocktail hour is at 6 p.m., dinner at 7 p.m., and program at 8 p.m. Reservations should be made by Wednesday, April 14, with either Mike York in Corvallis (phone 757-0349) or the Oregon Department of Geology and Mineral Industries receptionist in Portland (phone 229-5580). □

DOGAMI publishes new geologic map of Bourne quadrangle, eastern Oregon

A new geologic map for a part of eastern Oregon, published by the Oregon Department of Geology and Mineral Industries (DOGAMI), shows gold and silver mines and prospects as well as the geology of a historic mining area.

The multicolored map, *Geology and Gold Deposits Map of the Bourne Quadrangle, Baker and Grant Counties, Oregon*, was prepared by H.C. Brooks, M.L. Ferns, R.I. Coward, E.K. Paul, and M. Nunlist and appears in DOGAMI's Geological Map Series as Map GMS-19. At a scale of 1:24,000, it delineates 11 different bedrock and surficial geologic units, identifies 61 gold and silver lode and placer mines and prospects, and indicates known quartz veins. In three cross sections, it interprets basic geologic structure. Also printed on the map, partly in tabular form, is a summary of geologic and historical data for the deposits.

The Bourne 7½-minute quadrangle covers a part of the northwest corner of Baker County and about one square mile of Grant County. The region's mining areas, especially the North Pole-Columbia lode and the Cracker Creek, Cable Cove, and Rock Creek mining districts, are well known from their active periods between 1895 and 1940, when their total production value was an estimated $11 million.

DOGAMI Map GMS-19 is available now at the Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $5.00. Orders under $20.00 require prepayment. □

Available publications

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	$ 1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart, and Stewart, 1949: v. 2	1.25		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
61. Gold and silver in Oregon, 1968: Brooks and Ramp	17.50		
62. Andesite Conference guidebook, 1968: Dole	3.50		
65. Proceedings of the Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976: Peterson and others	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, Oregon, 1979: Bela	9.00		
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
102. Bibliography (7th supplement) geology and mineral resources of Oregon, 1976-1979, 1981	4.00		
SPECIAL PAPERS			
1. Mission, goals, and programs of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00		
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00		
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon, 1979: Allison	4.00		
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00		
9. Geology of the Breitenbush Hot Springs quadrangle, Oregon, 1980: White	4.00		
10. Tectonic rotation of the Oregon Western Cascades, 1980: Magill and Cox	3.00		
12. Geologic linears of the northern part of the Cascade Range, Oregon, 1980: Venkatakrishnan, Bond, and Kauffman	3.00		
13. Faults and lineaments of the southern Cascades, Oregon, 1981: Kienle, Nelson, and Lawrence	4.00		
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian (USGS I-325), 1961	3.50		
Geologic map of Oregon east of 121st meridian (USGS I-902), 1977	5.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
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COVER PHOTO

An example of the ammonite genus *Euhoploceras* from the Snowshoe Formation in the Suplee area, east-central Oregon. Maximum diameter of specimen is 13.5 cm. See article beginning on next page.

OIL AND GAS NEWS

Columbia County:

Reichhold Energy Corporation continues to carry out exploratory drilling in Columbia County, most recently spudding Crown Zellerbach 32-26 about 11 mi southeast of production at the Mist Field. This well, projected for 6,500 ft, is located in sec. 26, T. 5 N., R. 4 W.

The company also anticipates redrilling two existing wells at Mist: Columbia County 4 and 13-1.

Douglas County:

Florida Exploration Company of Houston has begun drilling northwest of Roseburg in Douglas County. A Montgomery rig from California spudded the well, Florida Exploration Company 1-4, on April 6 and is drilling toward a proposed depth of 10,000 ft. The well is in sec. 4, T. 21 S., R. 6 W. The operator has also applied to drill a second well in Douglas County (see table below).

Malheur County:

It has been over 20 years since an oil and gas well has been drilled in northern Malheur County, although several of the earlier wells had shows of gas. Z & S Construction Company of Kimball, Nebraska, will soon bring the oil and gas search back to the Vale area with a well to be drilled in sec. 9, T. 19 S., R. 44 E. The proposed depth is 4,850 ft.

Recent permits:

Permit no.	Operator, well, API	Location	Status
210	Reichhold Energy Crown Zellerbach 34-26 009-00101	SE¼ sec. 26 T. 5 N., R. 4 W. Columbia County	Permit issued
211	Reichhold Energy Crown Zellerbach 32-26 009-00102	NE¼ sec. 26 T. 5 N., R. 4 W. Columbia County	Spud 3/26/82
212	Z & S Construction Recla 1 045-00023	SE ¼ sec. 9 T. 19 S., R. 44 E. Malheur County	Application
213	Florida Exploration Co. USA 1-25 019-00015	NW ¼ sec. 25 T. 24 S., R. 8 W. Douglas County	Application

□

CONTENTS

Jurassic shallow marine invertebrate depth zones, with exemplification from the Snowshoe Formation, Oregon

by David G. Taylor, Earth Sciences Department, Portland State University, Portland, Oregon 97207

INTRODUCTION

The Jurassic System historically has been associated with the development of concepts important for paleontology. Its classic terrane, in Europe, was the proving ground for such principles as faunal succession (William Smith), refined faunal zonation (Albert Oppel) and stages (Alcide d'Orbigny), and for the conceptualization of facies (Armanz Gressly). Jurassic molluscan-dominated shelly faunas have been the source of a profusion of monographs and even some detailed paleoecologic studies. Yet, to this day we have no comprehensive model for the shelly invertebrate depth zonation in the Jurassic shallow marine environment. Provinciality in the Jurassic was modest, which suggests that we may seek a general model of the paleobathymetric faunal distribution, just as has been accomplished for parts of the Paleozoic (Berry and Boucot, 1972; Boucot, 1975).

Our accumulated knowledge of Jurassic paleontology centers on Europe. It is the only region where marine invertebrate faunas are well known and, with a few exceptions, is the source for detailed paleoecologic study. Our knowledge of the Jurassic is weighted heavily toward the epeiric environment, which typifies northwest Europe.

The Jurassic of the Western Cordillera of the United States consists of thick eugeosynclinal sequences that have received comparatively little study paleontologically, with the notable exception of the numerous articles by Imlay (1980, for summary). The neglect may have resulted partly from the belief by many that eugeosynclinal terranes are unsuited for refined paleontologic work. This attitude is best exemplified in the statement of a prominent Jurassic stratigrapher contrasting the Jurassic in the Western Interior with the West Coast sequences: "The facts attest conclusively to an environment of low topographic relief and considerable tectonic stability [in the Western Interior], in sharp contrast to the situation in California and neighboring states, where distinguishable rock formations cannot be traced over any great distance, and the great sedimentary thicknesses, poor fossil content and subsequent tectonic complications combine to rule out fine stratigraphic analysis" (Hallam, 1975, p. 123).

Volcaniclastic sequences are, in fact, prime subjects for conducting refined stratigraphic and paleontologic studies. Because such strata characteristically display rapid lithofacies changes, a wide spectrum of onshore to offshore depositional environments and accompanying faunal trends may be traced along coeval strata over distances of just a few kilometers. These rocks also are typified by numerous tuff beds, and where tuff-bed sequences and ammonite successions can be interrelated, precise correlation is the rule. Detailed, stratigraphically based studies in such rocks, therefore, potentially are amenable to exceptionally refined basinal analysis. The Snowshoe Formation in the Suplee area is a case in point (Figures 1 and 2) (Taylor, 1977, 1981).

The study of the Snowshoe Formation reveals a full range of inferred intertidal to basinal paleocommunities (studied quantitatively by this author, 1981), which in their stratigraphic context provide the basis for a model of the shallow marine depth zonation. Comparison of the faunas from the Western Cordillera, Western Interior, and Europe demonstrates the applicability of the zonation over wide areas and in the disparate settings of the eugeosynclinal and epeiric environments. This suggests that the nearshore to offshore distributional pattern of the invertebrate fauna documented initially in Oregon provides a model of general significance for the Jurassic.

The zones may be recognized by characteristic, depth-related clusters of paleocommunities or by unique co-occurrences and relative abundances of taxa (Figures 3 and 4). Boucot (1975) applied the term "benthic assemblage" (= marine benthic life zone of Berry and Boucot, 1971, 1972) to groups of benthonic communities that are depth related. Boucot (1975) also suggested the use of parallel sets of planktonic assemblages where appropriate. To facilitate a holistic approach, the term "composite assemblage" is proposed here for depth-related faunal associations and combinations of taxa encompassing all preserved fauna. In the definition of the composite assemblage, emphasis is placed on the bathymetric overlap in diversity and abundance of higher (supra-familial) taxa and certain ecologic groups (e.g., benthonic, nektonic, and planktonic taxa), because these are expected to retain a relatively stable arrangement, both temporally and geographically.

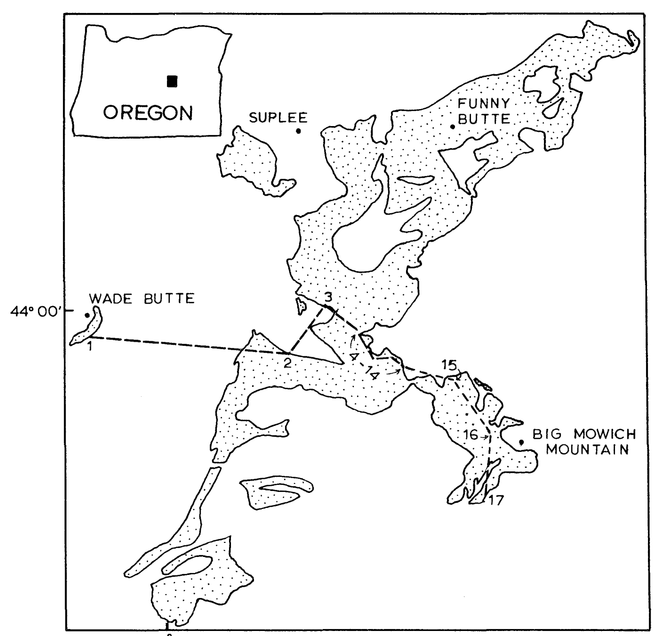

Figure 1. Location map showing distribution of Snowshoe Formation (stippled) in the Suplee area. Numbers along transect (dashed line) indicate locations of stratigraphic sections.

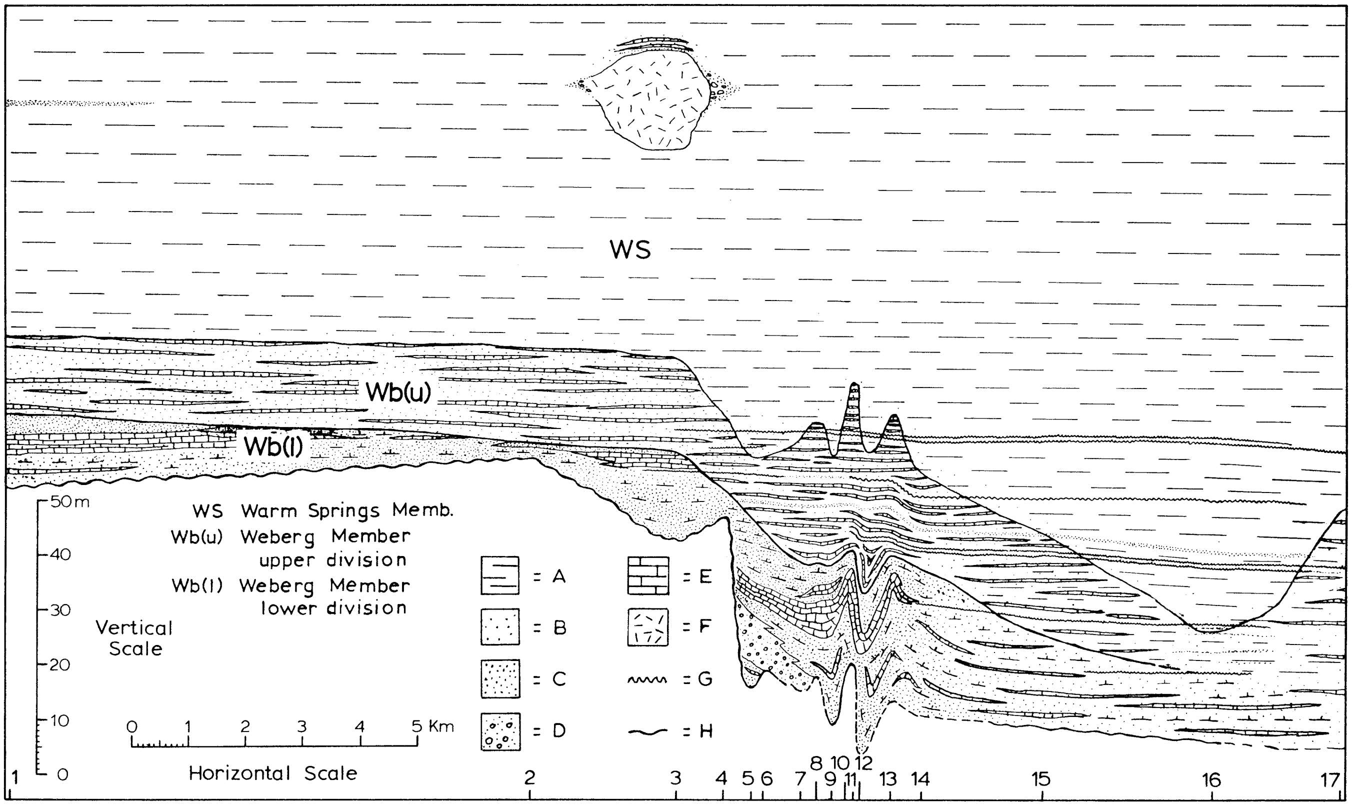

Figure 2. Cross section giving lithologies in the Snowshoe Formation in the Suplee area. Numbers at bottom indicate relative positions of stratigraphic sections, locations of which are shown in Figure 1. Lithologies are as follows: A = mudstone; B = coarse siltstone to very fine sandstone; C = fine to coarse sandstone; D = conglomerate; E = limestone; F = andesite; G = tuff bed; H = unconformity.

THE SNOWSHOE FORMATION

Stratigraphy

The Snowshoe Formation crops out extensively in the Suplee-Izee area (Dickinson and Vigrass, 1965) and is part of a thick Jurassic volcaniclastic sequence in the forearc-basin terrane of Brooks (1979). The formation in the Suplee area is entirely Middle Jurassic (Bajocian) in age and consists, in stratigraphic sequence from lowest to highest, of the Weberg Member (calcareous sandstone), Warm Springs Member (mudstone), and Basey Member (andesitic sandstone) (Dickinson and Vigrass, 1965). A stratigraphically higher member, the "Shaw" of Dickinson and Vigrass (1965), is now considered to be a westward extension of the Trowbridge Formation (Imlay, 1973, 1981; Smith, 1980). This study centers on the richly fossiliferous Weberg and Warm Springs Members.

Because the formation transgressed toward the west in the Suplee area, progressively offshore deposits can be traced upsection at any locality and from west to east (in the lower part of the section) along coeval strata (Figure 2). The nearshore-offshore trends and inferred hydrodynamic regimes are indicated by the (1) geometry of the basin, (2) sedimentary structures, (3) sedimentary textures, and (4) abundance of tuff beds. Inshore lithologies interpreted to have been deposited in a high-energy regime characteristically are coarse grained and lack tuff beds. (The tuff beds were destroyed by intensive current and/or wave activity.) Offshore lithologies deposited in quiet water are characterized by fine-grained texture, thin parallel lamination, and abundant thin tuff beds.

THE FAUNAL GRADIENT

There is an excellent representation of higher taxa in the Snowshoe Formation. The fauna is bivalve dominated, as is typical of the Jurassic. Other important groups include the diverse ammonites, locally abundant brachiopods, and volumetrically predominant crinoids. Figure 5 illustrates the life habits of various invertebrates that are discussed below. Before faunal trends are outlined, comments are necessary concerning ammonite distribution and the life habit of offshore bivalves.

Because ammonites and nautilids are externally shelled cephalopods with phragmocones that were gas-filled, the problem of post-mortem shell drift must be considered (Reyment, 1958; Chamberlin and others, 1981; both provide additional references). The distribution of ammonites in the

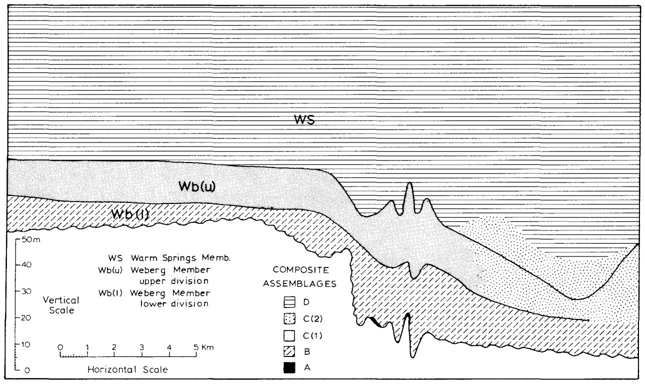

Figure 3. Cross section giving composite assemblages in the Snowshoe Formation. Composite Assemblage A represents the farthest inshore environment, while Assemblage D represents the basinal environment.

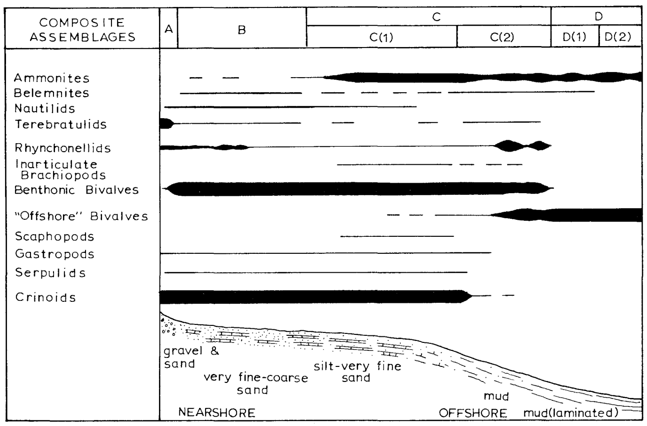

Figure 4. Schematic representation of the nearshore to offshore distribution and abundances of invertebrates in the Snowshoe Formation.

Snowshoe Formation suggests that post-mortem shell drift was an insignificant phenomenon. Ammonites are abundant only in a restricted environmental zone (Figure 6). They are rare in basal deposits, abundant in intermediate strata, and rare again in offshore deposits. This distributional pattern is not a preservational feature, because the ammonites found in areas where they are uncommon are reasonably well preserved. The transgressive nature of the belt of abundant ammonites demonstrates that it represents their habitat. If post-mortem shell drift were common, the shells would inevitably have been much more widely distributed in the inshore and offshore facies. Similar ammonite distributional patterns are characteristic of all of the Jurassic formations with which the author is familiar. It is clear that the ammonite distribution reflects their habitat and that the occurrence data are useful for analyzing the faunal bathymetric gradient. Ammonites apparently were unable to exploit the shallow-water, high-energy environment represented by the basal deposits of the Snowshoe Formation, as suggested, for example, by inferred musculature indicating poor swimming capabilities (Mutvei and Reyment, 1973; Kennedy and Cobban, 1976). While not enough nautilid (*Cenoceras*) specimens were collected to ascertain whether their distribution is that of their habitat, they are most common in the study area in facies inshore of ammonites. This inshore distribution may have occurred because the nautilids were better swimmers than the ammonites (Mutvei and Reyment, 1973).

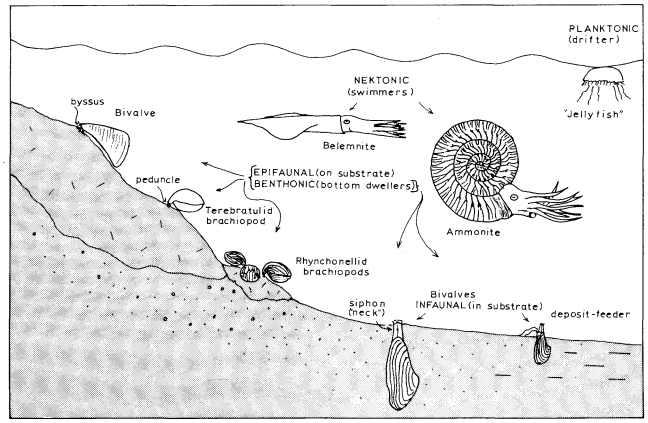

Figure 5. The life modes of certain Jurassic invertebrates, with an explanation of relevant terminology.

There is conjecture concerning the life habit of certain thin-shelled bivalves that occur typically in offshore argillaceous facies. *Bositra* is one such pelecypod which occurs in the Snowshoe Formation. The genus has been regarded variously to have had a planktonic or benthonic life habit (Jefferies and Minton, 1965; Kauffman, 1978). The decision was made to apply the noncommital term "offshore" bivalve to certain genera (*Bositra* and *Parainoceramus* in the Snowshoe Formation) having an offshore distribution in facies where there are few fossils proved to have been benthonic.

The sequence from nearshore to offshore of faunas, lithologies, and inferred depositional environments is described below (Figure 4).

Terebratulid brachiopods occur locally in the basal beds of the formation. Common associates are rhynchonellid brachiopods and bivalves that were capable of firm attachment to hard substrates. The associated lithologies are limestone and sandstone which commonly are pebbly. The inferred environment is one of extremely shallow water and high energy.

Farther offshore is a highly diverse fauna dominated by bivalves which along with the gastropods tend to be comparatively large and thick shelled. Terebratulids are uncommon, rhynchonellids are abundant locally, nautilids are rare but most common here, and ammonites usually are uncommon and not diverse. No "offshore" bivalves are present. The lithology typically is fine to coarse (commonly granule-bearing) sandstone and limestone. No tuff beds occur. The inferred environment is high-energy, as attested by the coarse-grained lithology and the absence of tuff beds.

The next fauna offshore is diverse and dominated by bivalves, most of which are small and weakly ornate. Most gastropods are small. Ammonites are abundant and diverse, articulate brachiopods are uncommon, and "offshore" bivalves are uncommon but do occur. The lithology is a very fine sandstone to coarse siltstone with numerous thin limestone interbeds. A few thicker (greater than 5 cm) tuff beds occur. The inferred environment is of lower energy than the previous one, but one in which current and/or wave activity were persistent.

The benthonic fauna becomes markedly less diverse farther offshore. Deposit-feeding bivalves are locally common, and "offshore" bivalves are abundant in places. Bivalves are small and weakly ornate. Rhynchonellids may be numerically dominant. The lithology is mudstone, which commonly is sandy. There are numerous thick tuff beds, but few thin ones.

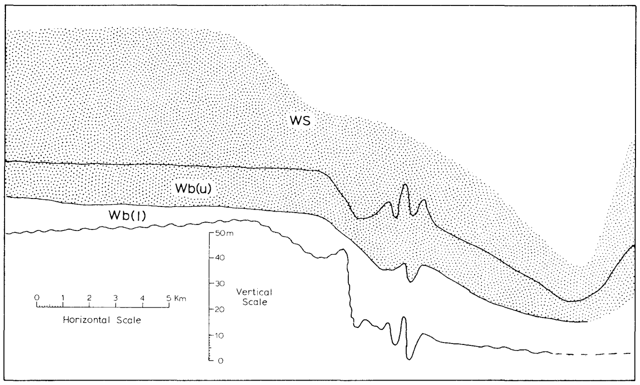

Figure 6. Zone of common ammonites (stippled) in the Snowshoe Formation. Wb(l) = Weberg Member, lower division; Wb(u) = Weberg Member, upper division; WS = Warm Springs Member.

The inferred environment is of somewhat lower energy than the previous one, as indicated by the finer rock texture and more common tuff beds.

The basinal environment yields abundant ammonites and "offshore" bivalves to the near exclusion of indisputed benthos. Ammonites are most diverse in the inshore part, where belemnites are restricted. The lithology is laminated mudstone with abundant thin beds and laminae of tuff. The inferred environment is one of very quiet water, as suggested by the fine-grained and parallel-laminated lithology and by the abundance of thin tuff beds.

Shelly macrofauna is rare farther offshore.

THE COMPOSITE ASSEMBLAGES

Three regions are considered in the following account of the composite assemblages. The first is the Western Cordillera of the United States (including Nevada), where the author has examined most of the stratal sequences. Assignments of the various faunas are based on field data and collections of the author, as well as on the literature. The formations from Oregon and northern California are eugeosynclinal, while those in Nevada (Sunrise Formation and marine part of Dunlap Formation) are epeiric.

The other two regions are the Western Interior of the United States and Europe. Both areas are dominated by epeiric deposits. The allocation to the composite assemblage sequence given below of faunas from the Western Interior is based primarily on the quantitative paleoecologic work of Wright (1973, 1974). Assignments of European faunas are restricted primarily to quantitatively based paleoecologic analyses (Duff, 1975; Fürsich, 1976a,b, 1977; Kauffman, 1978; Morris, 1979; Palmer, 1979) furnishing abundance data which permit allocations.

Composite Assemblage A

Characterization: This assemblage includes faunas from the intertidal to very shallow sublittoral, high-energy part of the gradient. Epifaunal (cemented, byssate, or pedunculate) taxa are numerically dominant where the substrate was hard. Brachiopods, particularly terebratulids, may be most abundant. Siphonate feeders such as *Tancredia* occur in sandstones. Species diversity is low.

Associated substrates: The faunas generally occur in coarse-grained lithologies.

Examples: Lower Jurassic faunas occurring in a position equivalent to this assemblage (or Assemblage B) in Oregon in the Robertson Formation include "reefs" and accumulations of the rudistlike bivalve *Plicatostylus* (= *Plicatostylus* "assemblage" of Batten and West, 1976) and the closely associated low-diversity fauna of *Nerinea*, commonly with terebratulids (= *Nerinea* "assemblage" of Batten and West, 1976). Similar Lower Jurassic faunas occur in California in the Thompson Limestone (Batten and Taylor, 1978), in Nevada locally near the top of the Sunrise Formation (Silberling, 1959; Smith, 1981), and in Oregon near the top of the Donovan Formation (Smith, 1981). Suggested intertidal environments in the Dunlap Formation (Toarcian?) in Nevada yield common rhynchonellid brachiopods and inferred algal mat or stromatolite structures (Stanley, 1971). Another Lower Jurassic occurrence is in the lower part of the Graylock Formation in Oregon, from "massive," algae-rich bioherms up to 23 m thick.

In the Western Interior the assemblage is represented in the Upper Jurassic by the *Tancredia transversa* association (Wright, 1974). In Europe the assemblage is not well documented by quantitative paleoecologic work. Terebratulids, nonetheless, are common locally in very shallow-water, high-energy environments (Ager, 1965).

Composite Assemblage B

Characterization: This assemblage yields diverse and mostly bivalve-dominated paleocommunities. All bivalve life-habit groups except perhaps infaunal deposit feeders are well represented in terms of species diversity and numbers of individuals. Overall, the bivalve and gastropod faunas from this assemblage are characterized by relatively large, ornate, thick-shelled taxa. Ammonites usually are uncommon, and "offshore" bivalves are not present.

Associated lithologies: Lithologies in the Western Cordillera are fine- to coarse-grained sandstone and sandy limestone sequences. Lithologies in the Western Interior typically are siltstones and sandstones and similarly textured limestones. In Europe, the lithologies consist of variously textured limestones, sandy shales, marls, limestones, and other lithologies (see Hallam, 1975, under "nearshore marine associations").

Examples: Lower Jurassic faunas attributed to this assemblage in the Western Cordillera are from (1) Oregon, from the Robertson Formation (Batten and West, 1976, *Modiolus* and infaunal "assemblages"), the Suplee Formation (Dickinson and Vigrass, 1965; Hallam, 1965; Smith, 1981), and the upper part of the Donovan Formation from a red sandstone (Smith, 1981); (2) California, from the Hardgrave Sandstone (Hyatt, 1892; Hallam, 1965); and (3) Nevada, from the Sunrise Formation (upper part of unit 5 and lower part of 6 of Muller and Ferguson, 1939, distinctive fauna includes *Weyla*, *Cardinia*, *Gresslya*, *Pholadomya*, large gastropods; and unit 8 of Muller and Ferguson, 1939, see Smith, 1981, for fauna). Included are Middle Jurassic faunas from California from sandy parts of the Potem Formation and Mormon Sandstone (Crickmay, 1933; Sanborn, 1960; Taylor, 1981).

In the Western Interior, paleocommunities that have primarily an inshore distribution include the Middle Jurassic *Trigonia americana*, *Meleagrinella curta*, and the *Pleuromya subcompressa* associations (Wright, 1974).

Most of the faunas described by Fürsich (1976a,b; 1977) from the Corallian of England and France are shallow-water ones, which may be assigned to this assemblage. The faunas described by Palmer (1979) from the Bathonian Hampen Marly and White Limestone Formations occur no farther offshore than this assemblage.

Composite Assemblage C

Characterization: This assemblage represents the lateral overlap of benthonic shelly faunas with diverse and abundant ammonites and/or "offshore" bivalves and is subdivided as follows: The faunas of Assemblage C(1) are primarily bivalve-dominated. Most bivalves and gastropods from this assemblage (and farther offshore assemblages) are smaller, less strongly ornate, and thinner shelled than those from Assemblage B. Brachiopods are uncommon (in United States at least). Ammonites are common and diverse. "Offshore" bivalves occur in the assemblage but are more common in assemblages representative of greater distance from shore. Composite Assemblage C(2) consists of benthonic faunas which commonly are dominated either by bivalves or rhynchonellids (in Western Cordillera). Deposit-feeding bivalves are well represented. "Offshore" bivalves occur sporadically but may be abundant. Ammonites are abundant locally. Noncephalopod diversity is moderate to low.

Associated lithologies: Rocks in the Western Cordillera associated with Assemblage C(1) usually are very fine sandstone to coarse siltstone sequences with numerous limestone beds. In the Western Interior, they are clays, with minor siltstone, fine sandstone, and thin limestone beds. In Europe, they commonly are nonlaminated clays and marls. Lithologies from the Western Cordillera commonly associated with Assemblage C(2) are sandy mudstones; in Europe, the lithologies are clays, shales, and mudstones that often are laminated.

Examples: Lower Jurassic occurrences in the Western Cordillera include Assemblage C(1) in the Sunrise Formation (lower part of unit 5 of Muller and Ferguson, 1939), Assemblage C(2) locally in the Suplee-Nicely formational transition, and Assemblage C(undifferentiated) in the Sunrise Formation in the upper part of unit 6 of Muller and Ferguson (1939). Assemblage C(2) occurs in the Middle Jurassic in the Mormon Sandstone (Taylor, 1981).

In the Western Interior Middle and Upper Jurassic, the *Gryphaea nebrascensis* (Upper Jurassic occurrence in "Upper Sundance Formation," personal observation) and *Camptonectes bellistriatus* associations have a paleogeographic position no farther offshore than that of Assemblage C.

In Europe, the most offshore associations from the Corallian as described by Fürsich (1976a,b; 1977), which typically occur in fine-textured lithologies, probably occur in a position no farther offshore than that of Assemblage C(1). Typical are the *Lopha gregaria* and *Oyster/Isognomon promytiloides* associations. Composite Assemblage C(2) is well represented in the lower Oxford Clay (Duff, 1975) and the Toarcian "restricted shale facies" at Yorkshire (Morris, 1979).

Composite Assemblage D

Characterization: This assemblage represents the occurrences of ammonites, nautilids, belemnites, and "offshore" bivalves over parts of the shelf that were offshore from those where indisputed shelly benthonic faunas thrived. The assemblage is divided tentatively as follows: Assemblage D(1) includes abundant and diverse ammonites. The dominant bivalve group is "offshore." Assemblage D(2) has ammonites and/or "offshore" bivalves, to the near exclusion of other taxa including belemnites, at least in the Middle Jurassic formations in the Western Cordillera. In eugeosynclinal regions of western North America, farther offshore areas only rarely furnish shelled macroinvertebrates.

Associated lithologies: Lithologies in the Western Cordillera primarily are laminated mudstones and, less commonly, sandy mudstones. The lithologies in Europe typically are laminated mudrocks or clays, which commonly are bituminous.

Examples: In the Western Cordillera, Lower Jurassic examples are from (1) Oregon, from the Hurwall Formation (Smith, 1981); (2) California, from the Sailor Canyon Formation (Imlay, 1967); and (3) Nevada, from parts of the Sunrise Formation (lower part of unit 7 and "black shales" in unit 9 of Muller and Ferguson, 1939).

No faunas from the Western Interior are referable to this assemblage. In Europe, the assemblage is documented where indisputed benthonic taxa are scarce in the Toarcian Posidonienschiefer (Kauffman, 1978) and in the coeval bituminous shale at Yorkshire (Morris, 1979).

DEPTH OF FAUNAS

The shelly faunas from the Snowshoe Formation thrived in shallow water. The short distances from inshore faunas to coeval basinal ones in the Snowshoe Formation (Figure 3) attest to the shallow-water environment (at most, just tens of meters deep) in which the benthonic shelly faunas lived. The depth limit of the "offshore" bivalves and ammonites is less certain. Shallow-water conditions are suggested in the Warm Springs Member, however, where an approximately 20-m-thick andesite flow is capped by about 3 m of shallow-water limestone beds containing sand- to pebble-size siliclastic detritus (Figure 2). The inferred shallow-water environment is consistent with suggested depth limits of perhaps 50-100 m (Hallam, 1975) for abundant and diverse benthonic shelly faunas (= Assemblages A-C) of this report.

COMPARISON WITH EUROPEAN BIVALVE "ECOLOGIC ASSOCIATIONS"

Hallam (1976) provided an account primarily of bivalve distribution in Europe by describing "ecologic associations." His "reefal" and "nearshore marine associations" have a paleogeographic position no farther offshore than that of Assemblage B, as indicated by numerous ornate and large bivalve genera and generally depauperate ammonite faunas. Paucity of ammonites and stratigraphic context suggest a similar shallow-water environment for the "lagoonal associations." His "marine basinal associations" are referable to farther offshore composite assemblages. The two divisions of the "marine basinal associations," termed "laminated bituminous shales" (faunas referable to Assemblages C(2) and D) and "nonbituminous bioturbated clay or marl" (faunas referable to composite assemblages no farther offshore than C(1)), are allocated to the composite assemblage sequence by the overall smaller size of bivalve individuals and by common "offshore" bivalves (in bituminous shales only) and ammonites. Hallam (1967a,b; 1975) at first misinterpreted the depth relationships of the bituminous shales and bioturbated clays and marls but later conceded the more basinal position of the bituminous facies (Hallam, 1978). While the account of the European "ecologic associations" is generalized, it nevertheless is consistent with the findings reported here.

CONCLUSIONS

The data indicate that (1) the depth zones documented stratigraphically for the Snowshoe Formation are applicable over a wide geographic area and to the epeiric as well as the eugeosynclinal suites, and (2) they provide a model of general significance for the Jurassic.

The model, being comprehensive, emphasizes the paleobathymetric distribution of the major invertebrate groups. The ammonites constitute one of the most diverse and abundant of these groups. The data from the Snowshoe Formation provide the most unequivocal evidence to date bearing on the problem of the importance of post-mortem drift of ammonite shells. The ammonites have a distributional pattern that clearly represents their habitat and, therefore, provides valuable information for the depth zonation.

The model manifests clearly the relative depths of the Jurassic seas over the three regions examined. As was to be expected, the eugeosynclinal Western Cordilleran region was deepest overall, as indicated by the thick mudstone sections containing only the most offshore faunas. Generally shallow-water conditions are indicated for northwest Europe, where facies such as the bituminous laminated shales (yielding offshore faunas) are developed rather sporadically (Hallam, 1978). Extremely shallow and/or restricted marine environments are indicated for the Western Interior by the documentation only of the inshore assemblages (A-C).

The model is expected to be a powerful tool for interpreting the basinal history of the Oregon Jurassic. Such study is certainly in order as an aid for deciphering the complex story that is unfolding concerning the tectonic collage which characterizes much of the Western Cordillera (Coney and others, 1980).

ACKNOWLEDGEMENTS

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"I'm Pterry, this is Ptom and this is Ptessa."

USGS publishes book on 1980 eruptions of Mount St. Helens

A report that summarizes the 1980 eruptions of Mount St. Helens in southwest Washington and the initial results of wide-ranging scientific studies of the volcanic activity and eruptive products has been published by the U.S. Geological Survey (USGS). The hard-bound, 844-page volume was designed and edited to be of interest to, and understandable by, a general audience as well as scientists. The 2-in.-thick book is extensively illustrated with maps, charts, and pictures, many of them in color.

It contains more than 60 separate articles by various authors mainly from the USGS but some from other government agencies, universities, and industry. The articles range from such technical subjects as "Petrography and particle-size distribution of pyroclastic-flow, ash-cloud and surge deposits" to more easily understood items such as a summary of eyewitness accounts and a description of "Growth of lava domes in the crater, June 1980-January 1981."

Editors of the book are Peter W. Lipman and Donal R. Mullineaux, both USGS geologists in Denver, Colo., who were members of the USGS monitoring and hazard-assessment team in the early weeks of the 1980 eruptive activity. Mullineaux and Dwight R. Crandell were the authors of a USGS report published in 1978 in which they predicted, based on their almost 20 years of study of Mount St. Helens, that the volcano would erupt again, probably explosively as it did May 18, 1980, and possibly before the end of the century. Crandell also was a member of the USGS Mount St. Helens team in 1980 but has since retired and works part time for the USGS.

USGS Director Dallas L. Peck said that the descriptions by Crandell and Mullineaux and their locations of potential hazards associated with possible eruptions of Mount St. Helens—such as pyroclastic flows, mudflows and flooding—proved accurate, with few exceptions, in the 1980 eruptions. "The volcanic-hazards assessment by Crandell and Mullineaux provided a key element in reducing hazards to life and property," Peck said.

The magnitude of the landslide and lateral blast on the north side of the volcano May 18, however, was unprecedented at Mount St. Helens and unexpected, said Mullineaux, Crandell, and C. Dan Miller, another USGS geologist in Denver, in their article in the book. The lateral blast extended about three times farther from the volcano than the largest known previous blast at Mount St. Helens, and it devastated an area that probably is 10 to 15 times larger. "The May 18 eruption of Mount St. Helens showed that catastrophic events can exceed any known precedent at a given volcano," the geologists said.

The book, titled *The 1980 Eruptions of Mount St. Helens, Washington*, was published as USGS Professional Paper 1250. Copies can be purchased, for $35 each, from the Branch of Distribution, U.S. Geological Survey, 604 South Pickett St., Alexandria, Va. 22304. Orders must include the identification number (PP-1250) and checks or money orders payable to the U.S. Geological Survey. □

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A revision to the estimate of the geothermal potential of Newberry Volcano

In the April 1982 issue of *Oregon Geology* (p. 44-46), the Na/Li geothermometer was used to estimate reservoir temperatures of 335°C, 375°C, and 370°C for East Lake Hot Springs, Paulina Hot Springs, and the Little Crater Campground warm well, respectively. These temperatures are, in fact, absolute temperatures (°K), and the correct estimates of reservoir temperature (based on the Na/Li geothermometer) are 62°C, 102°C, and 97°C. These results indicate that the Na/Li geothermometer is no better than the others for estimating reservoir temperatures based on the chemistry of the fumarolic springs at Newberry Volcano. Thus, while it is still quite possible that the reservoir temperatures at Newberry exceed 300°C, there is no firm basis for making such an estimate. All that can be said with certainty regarding the temperatures at Newberry is that a temperature of 265°C exists at a depth of 930 m in the USGS drill hole inside the caldera.

In light of the above information, a revision of Table 1 is in order.

Source of calculation	Reservoir volume (km^3)	Reservoir temperature (°C)	Reservoir thermal energy (10^{18}J)	Electrical (MWe for 30 years)
USGS Circ. 790[1]	47 ± 16	230 ± 20	27 ± 10	740
DOGAMI[2]	47	265	32	1,116
DOGAMI[3]	66	265	45	1,563
DOGAMI[4]	569	265	388	13,430

[1] Brook and others, 1979, p. 54.
[2] Oregon Department of Geology and Mineral Industries (DOGAMI) calculation, using reservoir volume estimate of Brook and others (1979) and new temperature data from Newberry 2 test well.
[3] DOGAMI calculation using increases in both reservoir temperature and volume from Newberry 2 hole (Sammel, 1981).
[4] DOGAMI calculation using volume estimate based on gravity work of Williams and Finn (1981).

It should be noted that while the above results are probably conservative with respect to temperature (the reservoir temperature should increase with depth), they are decidedly *not* conservative with respect to reservoir volume. In cases 3 and 4, the *maximum* possible reservoir volume has been used in making the estimates. Since reservoir volume controls the size of the energy estimates to a larger extent than does the reservoir temperature, the estimates must be considered highly optimistic overall.

—Gerald L. Black, Oregon Department of Geology and Mineral Industries □

Student AIME chapter forms at PSU

By vote of the Board of Directors of the Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers (SEM-AIME) on February 15, 1982, official status was awarded to the newly formed Portland State University Student Chapter.

Officers of the group are Tom Bessler, President; Roger Congdon, Vice President; and Carolyn Browne, Secretary-Treasurer. Faculty Advisor is Michael L. Cummings, Earth Sciences Department, Portland State University; Section Counselor is Beverly F. Vogt, Oregon Department of Geology and Mineral Industries. □

USGS lists early signs of possible landslides

On March 1, 1982, the U.S. Geological Survey (USGS) issued a press release regarding accelerated landslide activity in northern California during the past, extremely rainy winter season. Parts of that release are applicable to Oregon as well and are reproduced below:

"Large, deep slides can occur on weakened zones as much as several hundred feet below the ground surface and may be tens, hundreds, or even thousands of feet across. Rain water that seeps into the ground continues to migrate through tiny openings in the rocks to the water table. Additional water infiltrating the soil and reaching the saturated zone causes the water table to rise. This causes increased water pressures in the ground and reduces soil strength, particularly along previous fractures, and can trigger slides in slopes that had been stable during long dry periods. Old landslides may be reactivated, and new ones may form. The underground water continues to migrate long after the storms cease and can trigger additional landslides.

"The time and duration of landslide movement may vary widely—some slides may begin to move during a heavy storm; others may not move noticeably until weeks or months later when the rainwater has infiltrated to greater depths. The rates of landslide movement commonly are a few inches to a few feet per day but can be very rapid.

"Although higher rainfall has been recorded in the past, the higher rates preceded most of the large-scale urban development of the hillsides [in California]. Development has, in some places, occurred on old landslides, and in many places construction activities have resulted in the undercutting and steepening of slopes or the addition of weight to slopes in the form of fill and new structures, without, at times, adequate provisions for surface- and ground-water drainage or buttressing of unstable ground.

"The danger of landslide damage is expected to be greatly lessened in areas where grading ordinances, building regulations, and geologic and engineering advice have been available and complied with in the development of hillside areas. The present saturated conditions, however, will provide a severe test of the precautions that have been taken by local communities.

"Residents of buildings on or near steep slopes should, for their own safety, be particularly alert if new rainstorms bring additional heavy rainfall in the near future. Although debris flows move rapidly, most of them are small and can be avoided.

"As the rainy season continues, and for some time after, residents should also be alert to the early signs of possible impending damage from other, deeper-seated landslides. Such signs may include any one or more of the following:

- doors or windows that stick or jam for the first time;
- new cracks in plaster, tile, brickwork, or foundations;
- outside walls, walks, or stairs pulling away from the building;
- slowly developing and widening cracks in the ground or paved areas;
- breakage of underground utility lines;
- leakage from swimming pools;
- movement or tilting of fences, retaining walls, utility poles or trees; and
- new water seeps or bulging ground at base of slopes." □

MEETING ANNOUNCEMENTS

GSOC luncheon meetings

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

May 21—*Forty Floods*: by John Eliot Allen, Emeritus Professor of Geology, Portland State University.

June 4—*Waterways and Geology*: by James Seeley White, Personnel Manager, Oregon Department of Fish and Wildlife.

June 18—*A Nonexplosive Demolition Agent*: by John Hood, Engineering Geologist, Con-Rock Company.

Hydrotech Club luncheon meeting

The Hydrotech Club of Portland, founded in 1955 to promote interest in water, meets the fourth Friday of each month. Reservations are required and should be made by Thursday prior to the meeting by phoning 229-5683. The luncheon costs $5 and is at the Jasmine Tree Restaurant, 401 SW Harrison St., Portland. Parking is validated for the lot at 5th and Harrison. An alternative way to get to the meeting is to take bus 41, 42, 43, 44, or 45 from downtown.

May 28—*Inland Navigation in Oregon and Interstate Waters*: by Jack Stappler, Tidewater Barge Lines. □

Brownfield enters private sector

Michael E. Brownfield, Research Geologist with the Oregon Department of Geology and Mineral Industries since August 1980, has resigned his position to become Senior Coal Geologist with Consolidation Coal Company in Denver.

Brownfield's responsibilities with the Department included geologic mapping and coordination of efforts with university and federal geologists as part of the joint State—U.S. Geological Survey's revision of the geologic map of Oregon. He also coordinated collection of data from western Oregon and western Washington for the Correlation of Stratigraphic Units of North America (COSUNA) project, for which he also developed two generalized stratigraphic columns.

During his tenure with the Department, Brownfield wrote an article on coal in Oregon for *Oregon Geology* (v. 43, no. 5) and completed several mapping projects. He and co-author Herb Schlicker produced two open-file maps of the Amity and Mission Bottom quadrangles (0-81-5) and the McMinnville and Dayton quadrangles (0-81-6). Soon to be released as part of the Department's Geological Map Series are Brownfield's geologic maps of the Sheridan (GMS-23) and Grand Ronde (GMS-24) quadrangles. His work in these quadrangles has further clarified the stratigraphy of this part of the Oregon Coast Range, an area of widely variable interpretations in the past. His open-file maps of the Ballston (0-82-2) and Langlois (0-82-3) quadrangles will be released later this year. □

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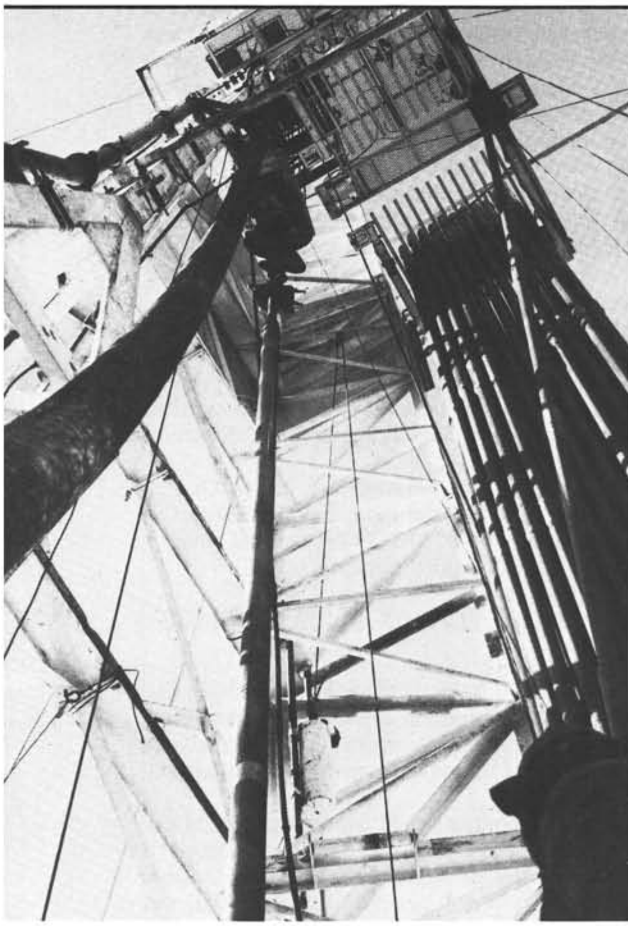

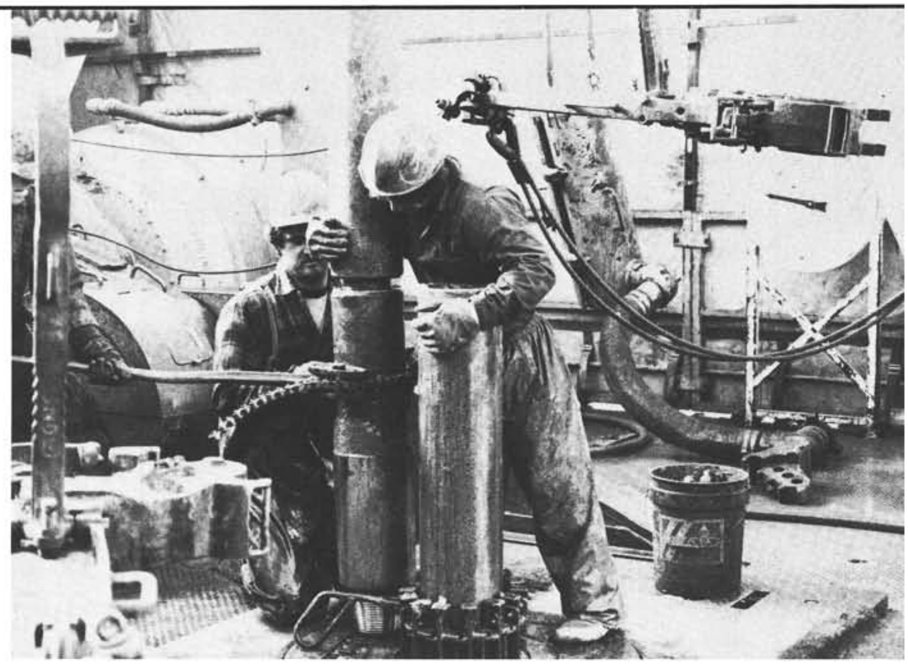

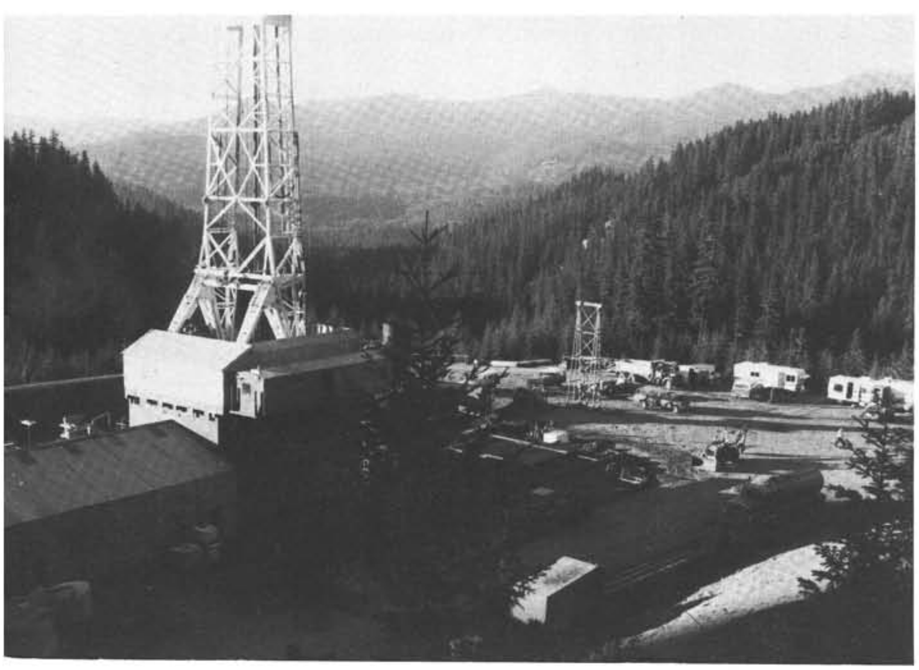

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COVER PHOTO

Sunoco's geothermal test well, drilled during fall of 1981, southeast of Breitenbush Hot Springs, Western Cascades. Article beginning on next page summarizes geothermal activity in Oregon during 1981.

DOGAMI publishes new geologic map of eastern Oregon mining area

A new geologic map by the Oregon Department of Geology and Mineral Industries (DOGAMI) covers the Mt. Ireland quadrangle, a traditional mining area on the border between Baker and Grant Counties.

The two-color map, *Geology and Mineral Resources Map of the Mt. Ireland Quadrangle, Baker and Grant Counties, Oregon*, was prepared by M.L. Ferns, H.C. Brooks, and J. Ducette and appears in DOGAMI's Geological Map Series as Map GMS-22. At a scale of 1:24,000, it delineates ten different bedrock and surficial geologic units and indicates quartz veins and mineralized fault zones. In addition, the map identifies 76 mine or prospect locations and describes them in a separate table.

Gold and silver from quartz vein and placer deposits have been the main mineral products of the quadrangle which covers most of the Cable Cove mining district and parts of the Cracker Creek and Granite districts. In addition to gold and silver, small amounts of lead, zinc, and copper have been recovered as by-products from the complex sulfide ores. Low-grade chromite deposits also occur in the area. Using historic values for gold and silver at the time of mining, total production value of the quadrangle has been about $1.2 million. Most of that production came from mines along the Bald Mountain-Ibex vein.

DOGAMI Map GMS-22 is available now at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $5.00. Orders under $20.00 require prepayment. □

USGS guidebook describes volcanic areas in northwest U.S.

A limited number of U.S. Geological Survey (USGS) Circular 838, *Guides to Some Volcanic Terranes in Washington, Idaho, Oregon, and Northern California*, are still available at the Portland office of the Oregon Department of Geology and Mineral Industries.

The 189-page book contains field trip guides for (1) Columbia River basalt between Lewiston, Idaho, and Kimberly, Oregon; (2) the area between Kimberly and Bend, Oregon; (3) central High Cascades, Bend, Sisters, McKenzie Pass, and Santiam Pass, Oregon; (4) Newberry Volcano, Oregon; (5) High Lava Plains, Brothers Fault Zone to Harney Basin, Oregon; (6) Fort Rock-Christmas Valley Basin, Oregon; (7) Medicine Lake Highland, Oregon-California; (8) Captain Jack's Stronghold, Lava Beds National Monument, California; and (9) the northern and western margins of the Medicine Lake Highland.

USGS Circular 838 is available free of charge to the public. A limited number of copies are available, one to a customer and over the counter only, at the business office of the Oregon Department of Geology and Mineral Industries, 906 State Office Building, in Portland. Free copies may be obtained by mail from the USGS, 604 S. Pickett St., Alexandria, VA 22304. □

CONTENTS

Geothermal exploration in Oregon, 1981

by George R. Priest, Gerald L. Black, Neil M. Woller, and William L. King, Oregon Department of Geology and Mineral Industries

ABSTRACT

Geothermal leasing and drilling in Oregon continued to increase in 1981 (Figure 1*). Drilling of a deep well near Breitenbush Hot Springs by Sunoco Energy Development Co. and discovery of steam at Newberry Crater by the U.S. Geological Survey (USGS) have greatly stimulated interest in the Oregon Cascades. Accelerated drilling and leasing should occur in the Cascades in 1982.

The highlight of activity in eastern Oregon centered around the Vale Known Geothermal Resource Area (KGRA), where GONRG, Inc., and Union Oil have done exploration. GONRG plans to install a 40-kW freon-cycle wellhead generator at Vale Hot Springs, and Union Oil drilled a 3,853-ft test well into the Cow Hollow heat-flow anomaly.

LEVEL OF DRILLING IN 1981

During 1981, the number of geothermal wells drilled and permits issued dropped slightly below the 1980 level (Figures 2 and 3). Drilling occurred on four of the seven wells which were permitted for depths greater than 2,000 ft (Table 1*). A total of at least 127 temperature-gradient wells was drilled to depths less than 2,000 ft (Table 2*). The overall emphasis of drilling appeared to be shifting from eastern Oregon toward the Cascades (Figure 1).

EXPLORATION IN EASTERN OREGON

The level of exploration in eastern Oregon was similar to 1980, the highlight being a 3,853-ft well drilled by Union Oil in the Cow Hollow heat-flow anomaly south of Vale. Results from this hole are confidential. Shallow temperature-gradient drilling was also completed at Reinhart Butte adjacent to Vale by Technology International, Inc., and R.D. and R.T. Butler;

* Locations of areas discussed in text are shown in Figure 1; detailed information on all deep wells and prospect wells appears in Tables 1 and 2, respectively.

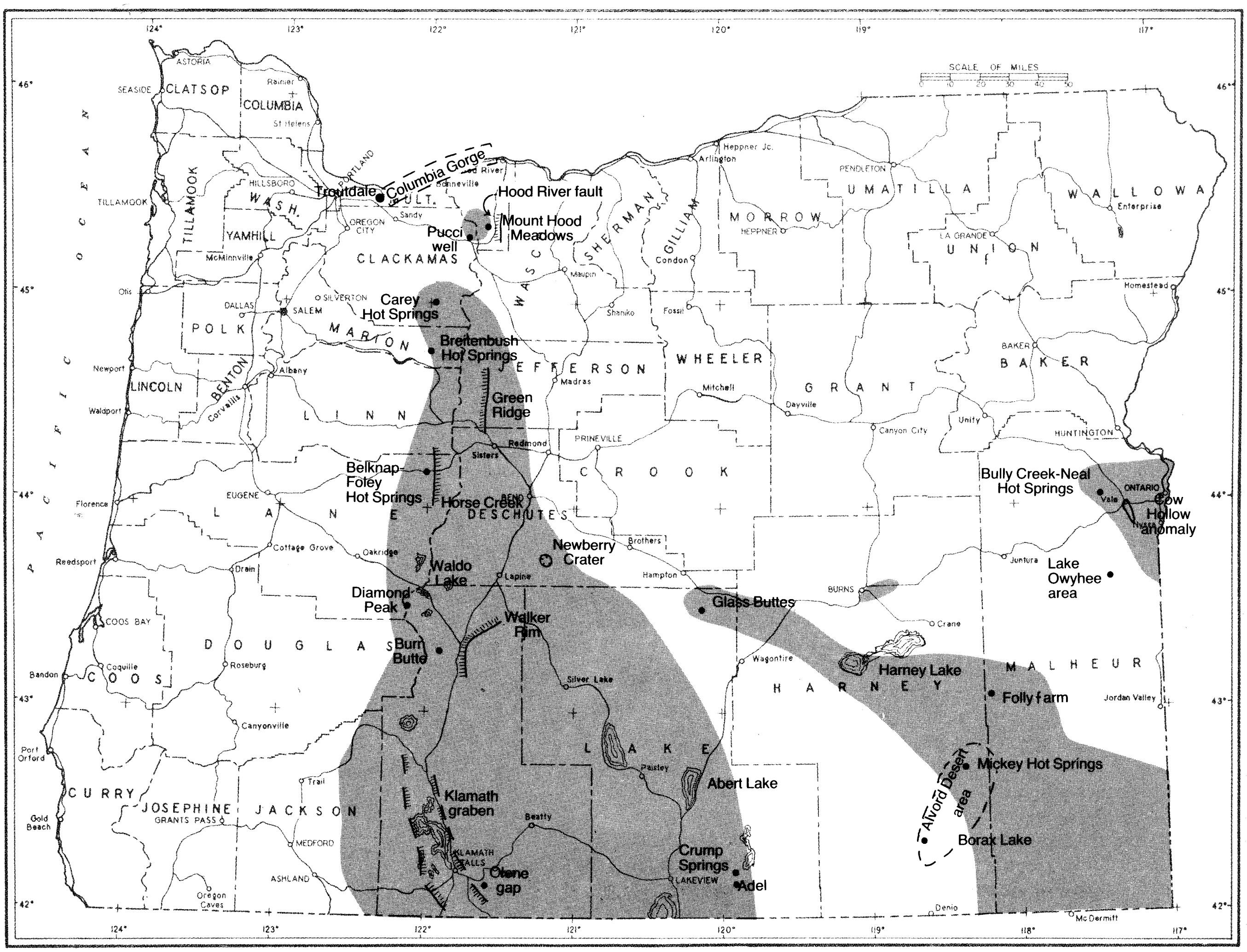

Figure 1. Location map. Some major fault scarps which have caused subsidence in the High Cascades heat-flow anomaly are shown with hachures on downthrown side. Areas with heat flow over 100 mW/m² shown in gray. (After Blackwell and others, 1978; Black and others, in preparation.)

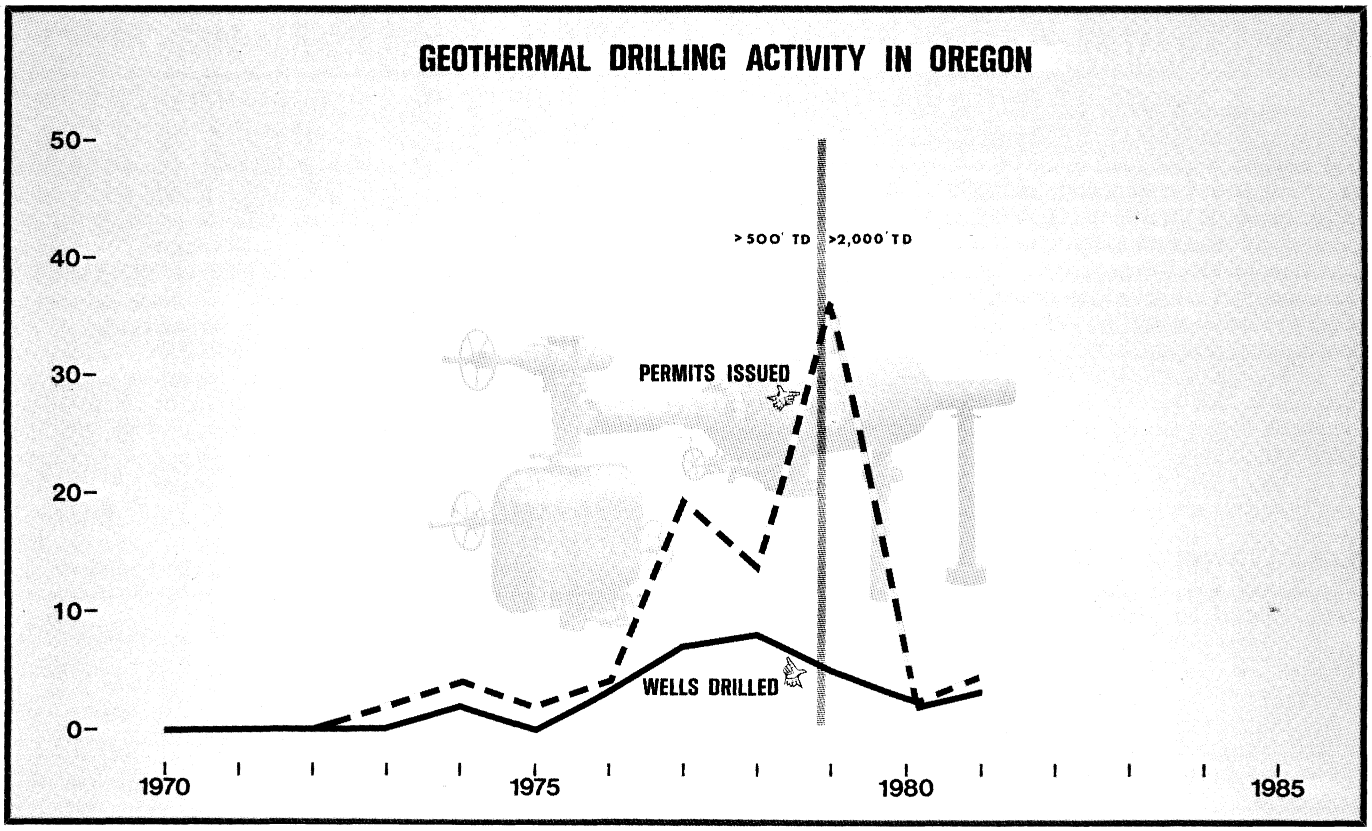

Figure 2. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 2,000 ft.

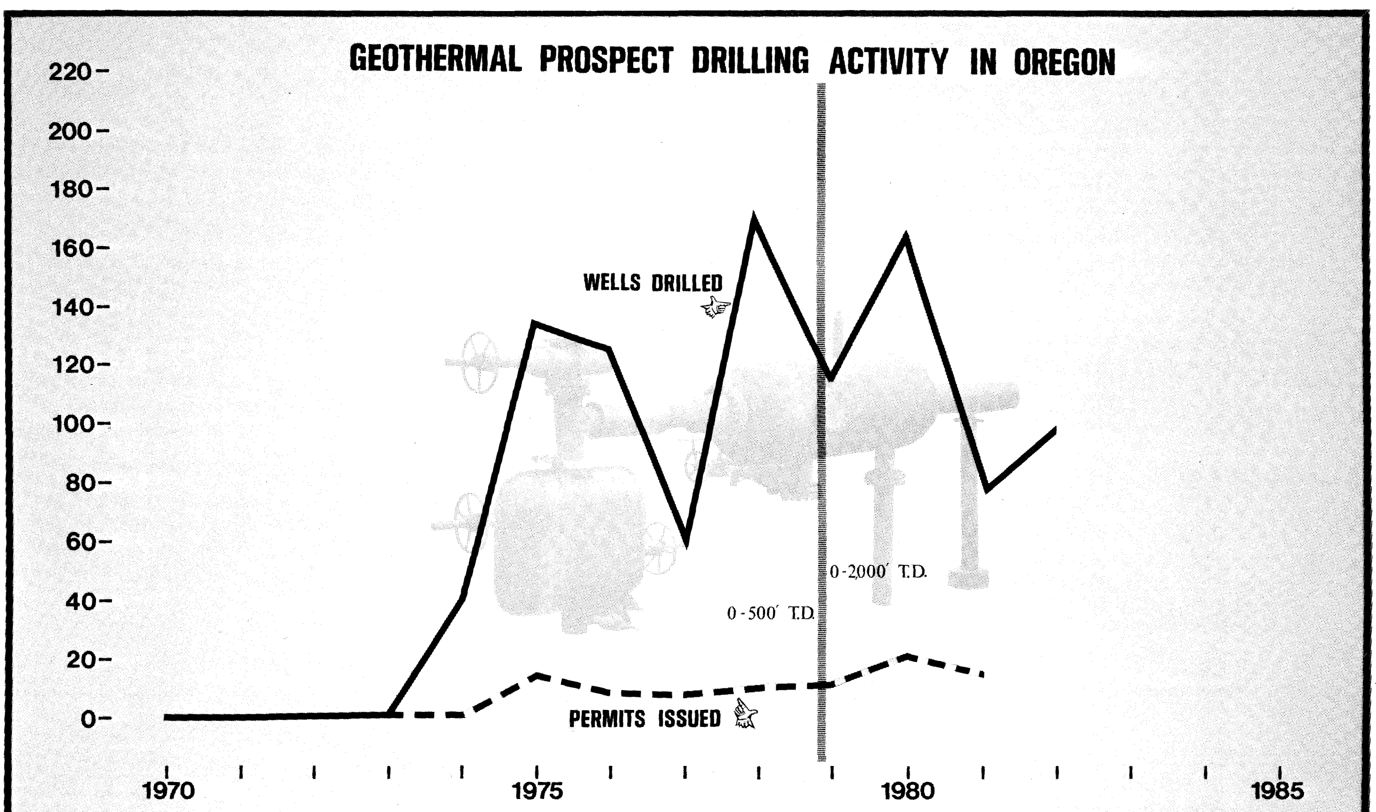

Figure 3. Geothermal prospect-well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth less than 2,000 ft.

Table 1. *Geothermal permits and drilling activity for wells greater than 2,000 ft in depth*

Permit no.	Operator and well name	Location	Status
45	U.S. Geological Survey Newberry Crater 2	SW¼ sec. 31 T. 21 S., R. 13 E. Deschutes County	Abandoned at 3,057 ft.
55	U.S. Geological Survey Mount Hood Meadows	SW¼ sec. 3 T. 3 S., R. 9 E. Hood River County	Deepened to 1,975 ft.
84	Northwest Geothermal Corp. Municipal Land 1	NE¼ sec. 15 T. 39 S., R. 20 E. Lake County	Location.
85	Sunoco Energy Development Co. Breitenbush 58-28	SE¼ sec. 28 T. 9 S., R. 7 E. Marion County	Suspended, confidential.
86	Union Oil of California Well 47-10	SW¼ sec. 10 T. 19 S., R. 45 E. Malheur County	Suspended at 3,853 ft.
87	Union Oil of California Well 83-4	NE¼ sec. 4 T. 19 S., R. 45 E. Malheur County	Location.
88	Union Oil of California Well 35-4	SW¼ sec. 4 T. 19 S., R. 45 E. Malheur County	Location.

Table 2. *Geothermal permits and drilling activity for wells less than 2,000 ft in depth (prospect wells)*

Permit no.	Operator and well name	Location	Issue date and status
49	Technology International, Inc.	Vale area, Malheur County	December 1980; drilled four gradient holes to 300 ft.
67	Hunt Energy Corporation	Lake Owyhee area, Malheur County	June 1980; drilled nine holes to 500 ft.
68	Oregon Department of Geology and Mineral Industries	Mount Hood National Forest, Hood River County	June 1980; location, three gradient holes.
73	Oregon Department of Geology and Mineral Industries	Upper Hood River Valley, Hood River County	November 1980; location, four gradient holes.
76	R.D. and R.T. Butler	Vale area, Malheur County	March 1981; drilled two gradient holes to 200 ft.
77	AMAX Exploration, Inc.	Bully Creek area, Malheur County	April 1981; drilled nine gradient holes to 330 ft, one gradient hole to 1,010 ft.
78	Union Oil of California	Western Cascades, Clackamas, Deschutes, Hood River, Jefferson, Lane, Linn, and Marion Counties	June 1981; drilled eighteen gradient holes to 500 ft.
79	Oregon Department of Geology and Mineral Industries	Harney Basin, Harney County	June 1981; re-entered old well to monitor subsurface temperature.
80	Phillips Petroleum Company	North-central Cascades, Clackamas, Lane and Marion Counties	June 1981; drilled 13 gradient holes to 500 ft.
81	Anadarko Production Company	Borax Lake area, Harney County	July 1981; drilled four gradient holes to 500 ft.
82	Francana Resources	Glass Buttes area, Lake County	July 1981; drilled three gradient holes to 1,300 ft.
83	Oregon Department of Geology and Mineral Industries	Troutdale-Columbia Gorge area, Hood River and Multnomah Counties	July 1981; drilled six gradient holes to 500 ft.
84	Chevron Resources	Belknap area, Lane County	August 1981; drilled six gradient holes to 970 ft.
85	Chevron Resources	Mount Hood National Forest, Marion and Clackamas Counties	August 1981; drilled six holes to 500 ft.
86	Hunt Energy Corporation	Adel area, Lake County	September 1981; drilled nineteen gradient holes to 500 ft.
87	Anadarko Production Company	Alvord Springs area, Harney County	September 1981; drilled three gradient holes to 500 ft.
88	Oregon Department of Geology and Mineral Industries	Burns area, Harney County	October 1981; drilled one gradient hole to 575 ft.
89	John W. Hook and Associates	Bend area, Deschutes County	October 1981; five gradient holes.
90	Hunt Energy Corporation	Lakeview area, Lake County	October 1981; drilled nine gradient holes to 500 ft.
91	Renewable Energy, Inc.	Vale Butte, Malheur County	December 1981; location, one gradient hole.

at Lake Owyhee by Hunt Energy Corp.; at Bully Creek and in the Adel area by AMAX Exploration, Inc.; near Borax Lake by Anadarko; and at Glass Buttes by Francana Resources, who drilled three 1,300-ft gradient holes.

EXPLORATION IN THE CASCADES

Exploration activity in the Oregon Cascades increased dramatically in 1981. Discovery of steam at Newberry Crater and drilling of a deep hole near Breitenbush Hot Springs should encourage similar high levels of exploration in 1982.

Newberry Crater

Discovery of temperatures of 509° F (265° C) and steam in the bottom of the 3,057-ft diamond-drill hole drilled by the USGS at Newberry Crater was the big news in the Oregon Cascades (Sammel, 1981). This discovery will probably increase interest in not only the Newberry area but also the rest of the Cascades in Oregon, Washington, and northern California. The hole clearly showed that a high-temperature geothermal system can go undetected by drilling programs aimed at depths of less than 2,000 ft in youthful volcanic terranes (e.g., see temperature log in Sammel, 1981). Consequently, the number of deep wells drilled in the Pliocene and younger volcanic rocks of the High Cascades can be expected to increase in coming years.

Shallow temperature-gradient drilling by industry

The Oregon Department of Geology and Mineral Industries (DOGAMI) completed much of its drilling program along

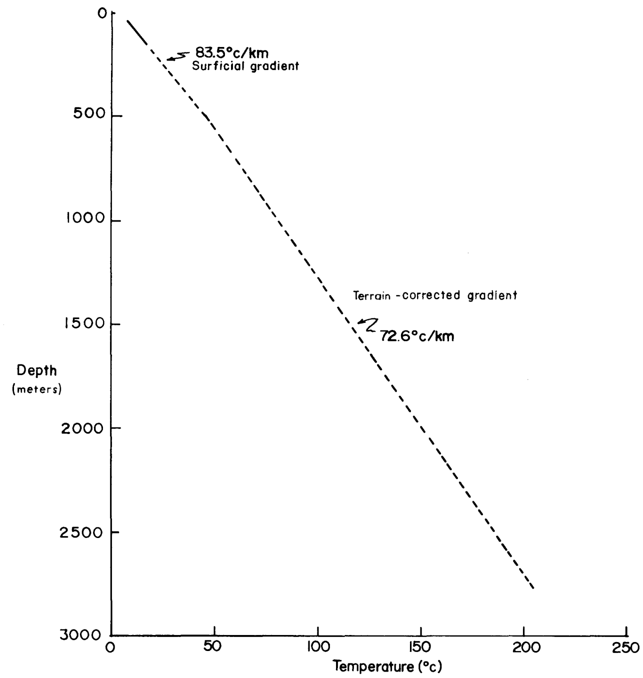

Figure 4. Terrain-corrected temperature-depth plot for the Devils Creek hole (NE¼ NE¼ sec. 11, T. 10 S., R. 7 E.) drilled by DOGAMI in 1979. Dashed line shows the gradient projected beyond the drill depth of 500 ft down to 9,000 ft. Actual temperature at 9,000 ft may be somewhat lower because of probable increase of thermal conductivity with depth.

the western boundary of the High Cascade heat-flow anomaly in 1980. The 1981 publication of temperature gradients obtained in the program (Blackwell and others, 1981) and earlier heat-flow data (Blackwell and others, 1978) stimulated major shallow drilling programs by industry in the north-central Cascades. Union Oil, Phillips Petroleum, and Chevron Resources all conducted extensive shallow drilling programs.

The Breitenbush deep well

Sunoco Energy Development obtained a permit for a 9,000-ft test well and drilled it during the fall of 1981 on Devils Creek, southeast of Breitenbush Hot Springs. The hole was completed to an undisclosed depth after a few months of drilling. A gradient of 83.5° C/km was found in a nearby 500-ft hole drilled by DOGAMI in 1979, also on Devils Creek. Because late Miocene basalts encountered in the DOGAMI hole provided excellent drilling, it is likely that the Sunoco hole encountered few problems and probably reached close to the projected 9,000-ft depth, which would make it the deepest hole in the Cascades. If the surficial gradient of the above-mentioned DOGAMI hole held up at depth, about 200° C could have been encountered at 9,000 ft (Figure 4). It is not known if significant fluids were encountered in the Sunoco hole, but chemical geothermometry of Breitenbush Hot Springs indicates possible reservoir temperatures of about 149° C (Brook and others, 1979). Fluids would probably have to circulate to about 6,560 ft to reach this temperature near the Sunoco site.

USGS drilling at Mount Hood

The USGS deepened its Mount Hood Meadows drill hole and flow-tested the 4,000-ft Pucci chairlift deep well. The Mount Hood Meadows well was deepened from 1,165 to 1,975

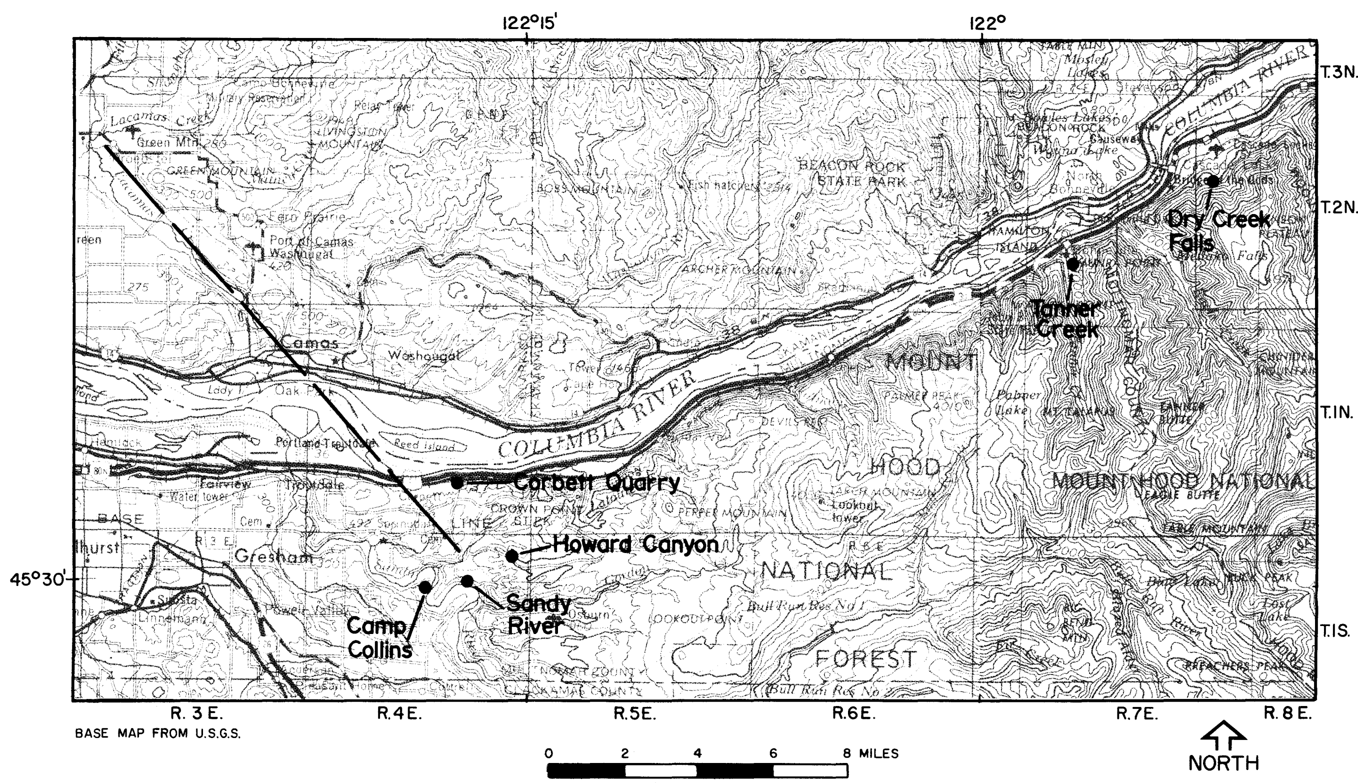

Figure 5. Locations of six shallow temperature-gradient holes drilled by DOGAMI in Troutdale-Columbia Gorge area in 1981. Tanner Creek—NE¼ NW¼ sec. 10, T. 2 N., R. 7 E.; Corbett Quarry—SW¼ SE¼ NE¼ sec. 27, T. 1 N., R. 4 E.; Howard Canyon—NW¼ SW¼ NE¼ sec. 1, T. 1 S., R. 4 E.; Sandy River—SW¼ SW¼ NE¼ sec. 11, T. 1 S., R. 4 E.; Dry Creek Falls—SE¼ SW¼ NE¼ sec. 16, T. 2 N., R. 8 E.; YMCA Camp Collins—NE¼ NE¼ NW¼ sec. 10, T. 1 S., R. 4 E. Lacamas fault zone is shown as dashed line.

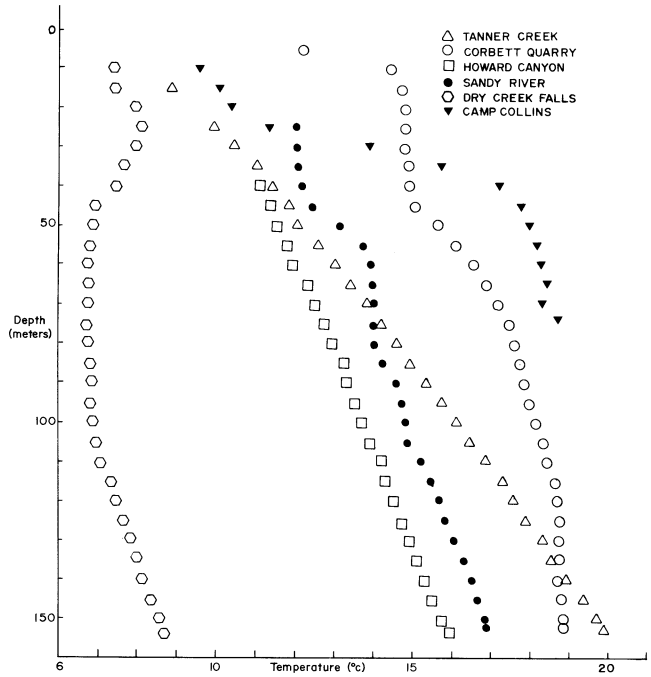

Figure 6. Temperature-depth plots for Troutdale-Columbia Gorge holes drilled in 1981 by DOGAMI. Dry Creek Falls temperature was measured before hole had stabilized.

ft and yielded a very good gradient of 81.7° C/km in the lower 650 ft of the well. The Pucci flow test recovered 110 gpm of water from a thermal zone with estimated temperature of 80° C (USGS news release, August 13, 1981). Unfortunately, the hole caved in below the casing, so further development for heating Timberline Lodge would require redrilling of all or part of the well.

DOGAMI drilling

Utilizing U.S. Department of Energy (USDOE) funds, DOGAMI completed six shallow temperature-gradient wells in the area extending from Troutdale into the Columbia Gorge (Figure 5). Preliminary temperature-depth curves for the holes are shown in Figure 6. No major temperature anomalies or thermal fluids were discovered in the holes near the Lacamas fault zone in the Troutdale (Corbett-Camp Collins) area, but anomalous gradients were encountered in the Columbia Gorge holes. Especially interesting is the Tanner Creek hole, which has a gradient of 77° C/km.

The USDOE-sponsored drilling program in the Oregon Cascades will terminate in the summer of 1982 with the drilling of several shallow temperature-gradient wells in the Ashland area in southwestern Oregon. This drilling program will be aimed at both discovering geothermal fluids adequate for direct use and defining the western margin of the High Cascade heat-flow anomaly.

GEOTHERMAL PUBLICATIONS

Several geothermal and geophysical publications related to geothermal exploration in Oregon were released by DOGAMI in 1981 (Table 3).

LEASING

The statistics on geothermal leasing activity in 1981 are summarized in Table 4. Issuing of leases continued mostly in areas of noncompetitive leasing on U.S. Bureau of Land Man-

Table 3. *DOGAMI geothermal publications released in 1981*

Open-File Reports

0-80-2-10 Preliminary geology and geothermal resource potential of [areas below], by D.E. Brown and others:
- 0-80-2 Belknap-Foley area: 58 p., 1 map.
- 0-80-3 Willamette Pass area: 65 p., 1 map.
- 0-80-4 Craig Mountain-Cove area: 68 p., 1 map.
- 0-80-5 Western Snake River Plain: 114 p., 4 maps.
- 0-80-6 Northern Harney Basin: 52 p., 4 maps.
- 0-80-7 Southern Harney Basin: 90 p., 8 maps.
- 0-80-8 Powell Buttes area: 117 p., 1 map.
- 0-80-9 Lakeview area: 108 p., 2 maps.
- 0-80-10 Alvord Desert area: 57 p., 2 maps.

0-80-11 Engineering and air and mud drilling data, DOGAMI well Old Maid Flat 7A: 1 sheet, folded into 16 p.

0-80-12 Geothermal gradient drilling, north-central Cascades of Oregon, by W.L. Youngquist: 47 p., 2 gamma-ray logs.

0-80-14 Progress report on activities of the low-temperature resource assessment program 1979-1980, D.A. Hull, principal investigator: 79 p.

0-81-2 Geophysical logs, Old Maid Flat well 7A, Clackamas County, Oregon: Folded log copies, 2 parts:
- 0-81-2A Shallow drilling (96-1,190 ft), 3 logs.
- 0-81-2B Deep drilling (96-5,952 ft), 9 logs.

0-81-3 Geothermal gradient data for Oregon, by Blackwell and others: 3 parts:
- 0-81-3A Data for 1978, 63 p.
- 0-81-3B Data for 1979, 98 p.
- 0-81-3C Data for 1980, 374 p.

Special Papers

9 Geology of the Breitenbush Hot Springs quadrangle, Oregon, by C.M. White: 26 p., 1 map.

12 Geologic linears of the northern part of the Cascade Range, Oregon, by R. Venkatakrishnan and others: 25 p., 5 maps.

13 Faults and lineaments of the southern Cascades, Oregon, by C.F. Kienle and others: 23 p., 1 map (2 sheets).

Geological Map Series

GMS-15 Free-air gravity anomaly map and complete Bouguer gravity anomaly map, Cascade Mountain Range, northern Oregon, by R.W. Couch and others: 2 maps, scale 1:250,000.

GMS-16 Free-air gravity anomaly map and complete Bouguer gravity anomaly map, Cascade Mountain Range, southern Oregon, by R.W. Couch and others: 2 maps, scale 1:250,000.

GMS-17 Total-field aeromagnetic anomaly map, Cascade Mountain Range, southern Oregon, by R.W. Couch and others: 1 map, scale 1:250,000.

Table 4. *Geothermal leases in Oregon, 1981*

Types of leases	Numbers	Acres	Relinquished leases Numbers	Relinquished leases Acres
Federal leases, active (new in 1981)				
Noncompetitive, USBLM	33	47,395	21	34,419
Noncompetitive, USFS	0	0	3	3,200
KGRA, USBLM	2	4,190	1	119
KGRA, USFS	0	0	0	0
Total	35	51,585	25	37,738
Federal leases pending (total since 1974)				
Noncompetitive, USBLM	46	135,352		
Noncompetitive, USFS	487	957,926		
KGRA, USBLM	0	0		
KGRA, USFS	0	0		
Total	533	1,093,278		
State (total since 1974)				
Total leases active in 1981	13	9,463		
Total applications pending	2	320		
Private (total since 1974)				
Total leases active (est.)	No data	200,000		

agement (USBLM) lands. As the U.S. Forest Service (USFS) begins to issue more leases, the number of active leases in the Cascades should increase considerably in the next few years.

In order to stimulate exploration, the Federal government will reoffer KGRA lands for competitive bidding and declassify lands now classified as KGRA's when no bids are received after several sales. A lease sale will be held on June 15, 1982, for about 107,800 acres on USFS and USBLM lands in the Summer Lake KGRA and on USBLM lands in the Alvord, Crump Geyser, Klamath Falls, and Vale KGRA's (Jackie Clark, USBLM, Portland Office, 1982, personal communication).

New areas which have been the focus of recent lease applications are the Cultus Lake, Devils Lake, Green Ridge, and Powell Buttes areas. Some areas continue to be ignored by industry even though, for geological reasons, they appear to have high potential. Areas which, in the writer's opinion, deserve more attention are (1) the Walker Rim; (2) the northeast and west sides of the Klamath graben; (3) the western margin of the south-central High Cascades province, especially at lineaments that may be fault zones which have caused major subsidence of the High Cascade axis (examples are areas due north of Diamond Peak, such as the escarpment on the west side of Waldo Lake and southern extensions of the Horse Creek fault zone mapped by Flaherty, 1981); (4) all areas of the High Cascade axis not within wilderness or national parks (essentially all of these areas in the southern Oregon High Cascades are unleased at present); (5) Burn Butte, north of Crater Lake; (6) the Follyfarm area north of the Alvord Desert; (7) the Harney Lake area; and (8) the Abert Lake area (Figure 1).

POSSIBLE FREON BINARY GENERATOR AT VALE

GONRG, Inc., of Ontario, Oregon, is planning to install a 40-kW freon-cycle, binary-fluid electrical generator at Vale Hot Springs. The small wellhead generator should be installed early in the summer of 1982, if financial backing is secured. The generator will utilize 60 gpm of 230° F water from a 200-ft well near the hot springs; 150 gpm of 55° F water will be necessary for cooling the working fluid (R.T. Butler, 1982, personal communication).

The project is strictly a research-and-development effort at present but may pave the way for a larger generating plant (perhaps 1 MWe) which could utilize the full potential of the shallow thermal waters. Should this project prove successful, it could mean that a large number of shallow geothermal sytems that have water in the 190°-250° F range could be cheaply exploited for electrical power production. Areas with measured temperatures within or near this range are Breitenbush Hot Springs, Carey (Austin) Hot Springs, Belknap-Foley Hot Springs, Klamath Falls-Olene Gap, Mickey Hot Springs, Borax Lake, Lakeview, Crump Springs, Neal Hot Springs, and the Collohan well at Paisley (Figure 1).

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OIL AND GAS NEWS

Columbia County

Reichhold Energy Corporation's Crown Zellerbach 32-26, located in sec. 26, T. 5 N., R. 4 W., near Pittsburg, was plugged and abandoned April 20, 1982. Total depth was 6,501 ft. Reichhold has one additional location in sec. 26, Crown Zellerbach 34-26, projected to a total depth of 6,000 ft.

Reichhold is currently redrilling Columbia County 13-1 in sec. 1, T. 6 N., R. 5 W. The original hole was completed August 15, 1981, as a gas well flowing 2.6 MMCFD. Total depth was 3,076 ft. Mechanical problems on the original hole necessitated this redrill operation.

Douglas County

Florida Exploration Company of Houston is drilling ahead on well 1-4, sec. 4, T. 21 S., R. 6 W. Florida has applied to drill three additional wells in Douglas County, one of which was previously reported in the May issue of *Oregon Geology*.

Malheur County

Z&S Construction Company of Kimball, Nebraska, spudded Recla 1 on April 29, 1982, in sec. 9, T. 19 S., R. 44 E., approximately 6 mi southwest of Vale. Projected total depth is 6,000 ft.

Recent permits

Permit no.	Operator, well, API	Location	Status
214	Florida Exploration Co. USA 1-22 019-00016	SE¼ sec. 22 T. 26 S., R. 8 W. Douglas County	Application
215	Florida Exploration Co. Eagles View Management 1-26 019-00017	NW¼ sec. 26 T. 20 S., R. 6 W. Douglas County	Application
216	Nahama & Weagant Klohs 1 071-00003	NE¼ sec. 6 T. 3 S., R. 2 W. Yamhill County	Application

□

BLM State Office changes location

All units of the Bureau of Land Management's (BLM) Oregon State Office have been moved to the Lloyd Center Tower at 825 NE Multnomah Street, Portland, OR 97208, according to William G. Leavell, State Director for BLM.

Phone numbers at the new location are the same as when the agency occupied two leased buildings on Oregon and Holladay Streets, a few blocks south of the new office. Likewise, the mailing address remains the same: P.O. Box 2965, Portland, OR 97208. With recent reorganization and decentralization, fewer employees are assigned to the State Office than before the move to different quarters.

For additional information, contact the BLM Public Affairs Office, phone (503) 231-6274. □

December 3, 1981, fireball

by Richard N. Pugh, Science Teacher, Cleveland High School, Portland, Oregon 97202

Down through the ages, human beings have watched "falling stars," or meteorites, and have often attached great significance to such spectacular events. Scientists, however, take a much more practical view of meteorites. These objects, which fall to earth from orbits around the sun, may be fragments of broken-up planets or bits of the original material from which the earth was formed. Studies of these meteorites, thus, provide insight into the composition of our earth as well.

Meteorites have a variety of compositions, ranging from "irons," which are primarily metallic iron alloyed with nickel, to "stones," which consist of silicates and resemble ultramafic rocks in composition. Because irons are more durable and more unusual looking, they are found more often and appear more frequently in museum collections. Descriptions of observed falls suggest, however, that stony meteorites are more common. We are printing the following article, which describes what may have been the falling of a stony meteorite into the Willamette Valley, in the hopes that bits of the meteorite may be found, thus adding to the body of information about the earth on which we live.

At 10:21, Pacific Standard Time, December 3, 1981, a meteoroid entered the earth's atmosphere over south-central Washington. The angle of entry was approximately 45° to the earth's surface. The direction of flight was south-southwest. The bolide (fireball), which illuminated an area of approximately 3,000 sq mi of the northern Willamette Valley, may have produced meteorites as well.

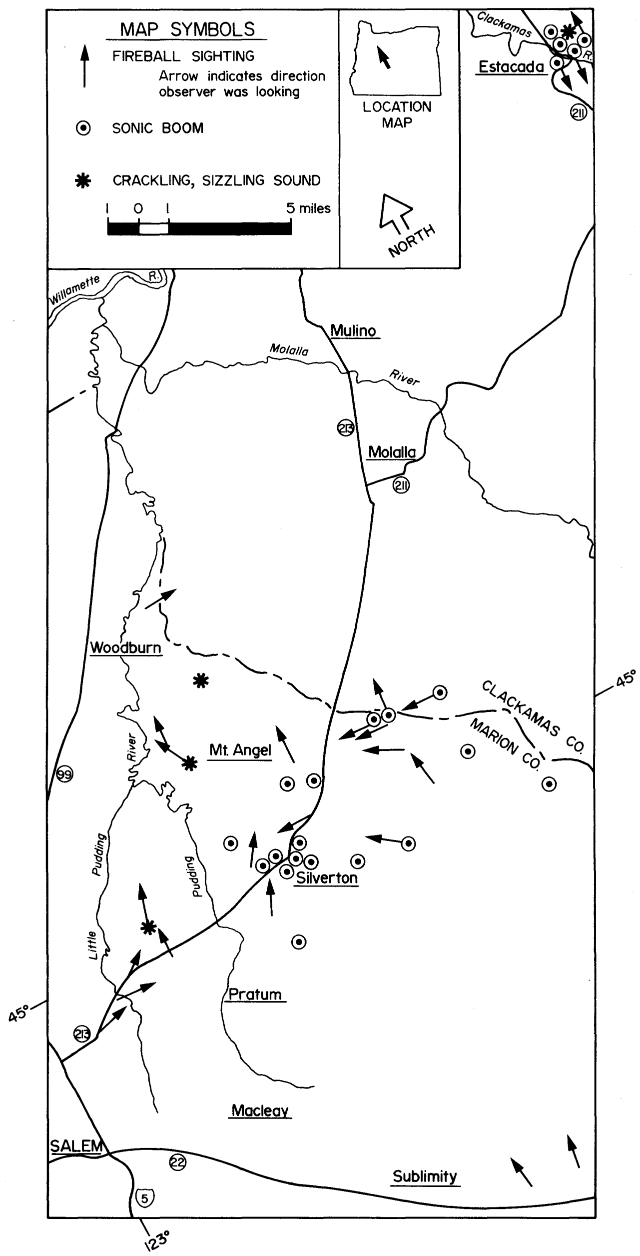
Over 100 people have already reported sightings and sound effects to the author. The fireball was seen as far east as Boardman, Oregon; as far north as Prosser, Washington; as far west as Astoria, Oregon; and as far south as Reedsport, Oregon. The observers east of the Cascades reported a kelly-green fireball, while the majority of the observers west of the Cascades saw a blue-white fireball. Most observers in western Oregon saw the fireball through a thin cloud layer or fog, and they reported the fireball to be the size of a full moon and somewhat brighter. The author estimates the fireball had a brightness of a magnitude of −13 (the moon has a magnitude of −12.7).

Sonic booms were heard from Portland in the north to Pratum in the south, and from Scotts Mills in the east to Salem in the west. The heaviest sonic booms occurred in the Scotts Mills-Silverton area. The sonic boom was reported to have rattled dishes and windows and in several cases to have knocked pictures askew on walls. The sonic booms were heard 1-1½ minutes after the fireball disappeared.

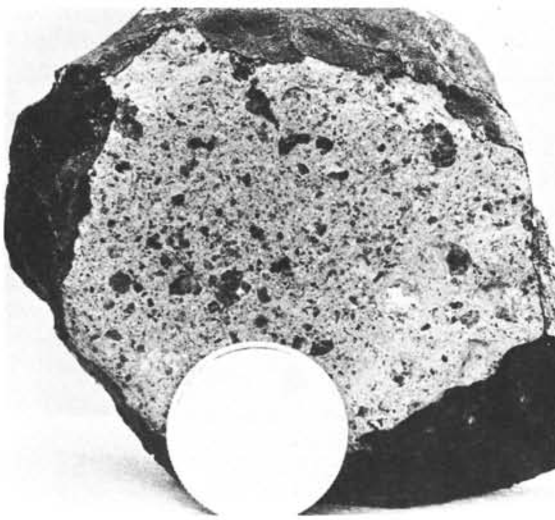
There were at least four reports of sizzling, crackling sounds heard at the same time as the fireball was seen. These sounds are unexplained, but they have been reported associated with other fireballs. These sounds are usually heard by those under the path of the fireball.

Several observers reported seeing the bolide disrupt over Estacada, with the larger fragments continuing down range toward the Silverton area. One person stated that the fireball exploded like a skyrocket. In the Silverton area, however, most observers reported a single object. This may be because most reporters were looking toward the north with the fireball coming toward them, which would make multiple fragments difficult to observe. One person in the Silverton area reported a large fireball with two smaller ones following it. Those people west of Silverton, at the end of the path of the fireball, observed the bolide moving slowly, coming almost straight downward, and then disappearing. Most of these observers heard no sound at all. It is not uncommon to have a cone of silence in front of a fireball. The meteoroid ceased producing light just west of Silverton.

By mapping the position of the observers and the direction from which they saw the fireball, I have concluded that the larger fragments could have landed as far south as Pratum,



Map showing areas where fireball was observed and most sound effects were heard. Path of the fireball was to the south-southwest.



The Washougal meteorite, a stony meteorite that is the only meteorite that was seen to fall and was then recovered in the Pacific Northwest. It is also the only stony meteorite recovered in the Northwest. It fell at 7:35 a.m., P.S.T., July 2, 1939, after a fireball exploded over Portland, Oregon. It is currently in the University of Oregon Museum collection. Round object is dime for scale.

Four Corners, and Macleay, just north of Highway 22. There could be smaller fragments of meteorite as far north as Estacada.

Since most of the meteorites entering the earth's atmosphere are stony, and since stony meteorites are brittle and tend to break up, it would seem reasonable to assume that this event was a stony meteorite that also disrupted, producing an elliptical area of impact. The larger fragments should be found southwest of Silverton, and the smaller fragments should be found around Mount Angel and perhaps as far north as Molalla and Estacada.

The meteorites will have a black or brown fusion crust on the exposed surface and will probably show rust due to our heavy rains. Flow lines and shallow depressions may be evident on the fusion crust.

The meteorites may have penetrated the ground a foot or two. Smaller fragments may be found in gutters or beside buildings where they rolled off roofs. Larger meteorites may have penetrated roofs.

Only four meteorites have been found in Oregon, and all of them were iron meteorites. It is hoped that some of the fragments from this fireball may be recovered. The finder of any specimens should contact the author at Cleveland High School, 3400 SE 26th Avenue, Portland, OR 97202, phone (503) 233-6441.

SUGGESTED READING

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Nature cannot be commanded except by being obeyed.
—*Sir Francis Bacon (1561-1626)*

Geologic map of parts of Polk and Yamhill Counties placed on open file

A new preliminary geologic map of the Ballston 7½-minute quadrangle in western Oregon has been placed on open file by the Oregon Department of Geology and Mineral Industries (DOGAMI).

Preliminary Geologic Map of the Ballston Quadrangle, Oregon, DOGAMI Open-File Report 0-82-2, was prepared by former Department staff member Michael E. Brownfield at a scale of 1:24,000. The blue-line map shows seven bedrock and surficial geologic units of Eocene and Pleistocene-Holocene age and includes a geologic cross section.

The Ballston quadrangle is situated on the border between Polk and Yamhill Counties, roughly within the triangle formed by McMinnville, Sheridan, and Dallas. The investigation of the quadrangle was part of a regional study of the northern Coast Range. It serves to link previous geologic mapping in the Willamette Valley with the new mapping project and will enable geologists to relate Willamette Valley geology to the geology of the central Oregon Coast Range.

Open-File Report 0-82-2 is now available at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $3.00. Orders under $20.00 require prepayment. □

Ocean hot spring still producing metals off Oregon coast

A plume of water containing the highest concentrations of manganese yet reported is still rising from an active submarine hydrothermal spring on the deep-sea Pacific floor 270 nautical mi west of Newport, Oregon. The discovery was first reported last September by researchers from the U.S. Geological Survey (USGS) Western Regional Center, Menlo Park, California, and from the University of Washington, Seattle, Washington. The initial announcement reported the occurrence of a series of metal deposits containing up to 60 percent by weight zinc and having significant amounts of silver, copper, and cadmium.

The stream of mineral-carrying water is being discharged by one of many submarine springs that have deposited large deposits of zinc- and silver-rich metals in an area of recent volcanic activity along the deep-sea Juan de Fuca Ridge, according to William R. Normark, USGS marine geologist and chief scientist on the discovery cruise by the USGS research ship *S.P. Lee*.

Followup laboratory analyses of water samples taken in the area by James Murray of the University of Washington have demonstrated the continuing activity and high metal content of the plumes above the vent. Murray reported water samples recovered from the vent area had dissolved manganese values that are greater than 100 times the normal background levels and that are the highest ever reported from water above hydrothermal vents.

Manganese carried in minute quantities in submarine hydrothermal discharge is known to be a reliable tracer of the hot vent water that deposits the rich metal deposits. At this location, very high manganese values were measured in a series of water samples from the sea floor and at several levels up to 500 ft above the sea floor. The persistent high values to that altitude indicate that this string of water samples was taken in a vertically rising plume of water from one of the vents.

The scientists from the USGS will return to the vent area in the fall of 1982. □

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COVER PHOTO

Eastward-dipping lower Coaledo outcrops near Coos Bay, Oregon. Photo shows Gregory Point with Cape Arago lighthouse at lower left, Cape Arago at upper right. Article beginning on next page presents data acquired from recent oil and gas exploratory drilling in the region that suggest revisions in the stratigraphic understanding of the Eocene Coaledo Formation. (Photo courtesy of Ward Robertson, Coos Bay, Oregon)

DOGAMI releases geothermal open-file reports

Geothermal-gradient data: The Oregon Department of Geology and Mineral Industries (DOGAMI) has released 1981 geothermal-gradient data for Oregon and placed them on open file as Open-File Report 0-82-4. The 430-page report contains temperature-gradient measurements taken by the DOGAMI geothermal staff in about 100 drill holes throughout the state. It includes a large number of new measurements in the Cascades and in eastern Oregon. The computer-produced report contains data tables and temperature-depth plots as graphic summaries for each of the drill holes.

Open-File Report 0-82-4, *Geothermal-Gradient Data, 1981*, was compiled by D.D. Blackwell, G.L. Black, and G.R. Priest, under contract to the U.S. Department of Energy, and is available for $15 from the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201.

Low-temperature geothermal-resource assessment: DOGAMI has completed its low-temperature geothermal-resource assessment of thirteen major prospects throughout the state, and the final report of this U.S. Department of Energy-sponsored project has been released as Open-File Report 0-82-5, *Oregon Low-Temperature Resource Assessment Program: Final Technical Report.*

The 53-page report summarizes assessment results for each of the following areas: Corbett-Moffets and Parkdale (Multnomah and Hood River Counties), Milton-Freewater (Umatilla County), La Grande (Union County), Belknap-Foley and Willamette Pass (Lane County), Powell Buttes (Crook County), Lakeview (Lake County), northern and southern Harney Basin and Alvord Desert (Harney County), and Western Snake River Plain and McDermitt (Malheur County). The raw data obtained in the three-year investigation have already been made available in earlier DOGAMI publications.

Low-temperature geothermal resources produce temperatures up to 90° C (194° F) and are considered mainly for direct use of hot geothermal water. The report points out that direct use of such hot water depends on its proximity to larger population centers for economic feasibility and is difficult in some low-population areas in the Cascades and eastern Oregon. However, new technologies are being tested now which will allow generation of electric power even from low-temperature resources. The report also confirms the very favorable geologic setting of the state for geothermal potential in general. The information gained in the completed program will aid the discovery of more and perhaps larger and hotter geothermal resources.

Open-File Report 0-82-5 sells for $5 and is also available from the Portland office of the Oregon Department of Geology and Mineral Industries. Prepayment is required for orders under $50. □

CONTENTS

Subsurface stratigraphic correlations of the Eocene Coaledo Formation, Coos Bay basin, Oregon

by Richard D. Robertson, Northwest Exploration Company, P.O. Box 5800 T.A., Denver, Colorado 80217

INTRODUCTION

In 1980, Northwest Exploration Company (NWE) of Denver, Colorado, drilled three oil and gas exploratory wells in the Coos Bay basin on the southern Oregon coast. All three wells penetrated the Eocene Coaledo Formation. Data acquired from these and other test holes revealed stratigraphic relationships within the Coaledo which are not evident in the frequently studied sea-cliff outcrops on the western side of the basin.

The Coaledo Formation, where exposed at the coast between Cape Arago and Yoakam Point (Figure 1), is approximately 6,600 ft thick. Turner (1938) divided the formation into three members. The upper and lower members are primarily sandstone, and the middle member is primarily mudstone. Open marine, marginal marine, and nonmarine facies are all represented. The Coaledo is overlain by the Bastendorff Formation and the Bastendorff by the Tunnel Point sandstone (Figure 2). A stratigraphic cross section using well data has been constructed across the basin in order to relate the coastal outcrops to the basin interior (Figure 3, Table 1).

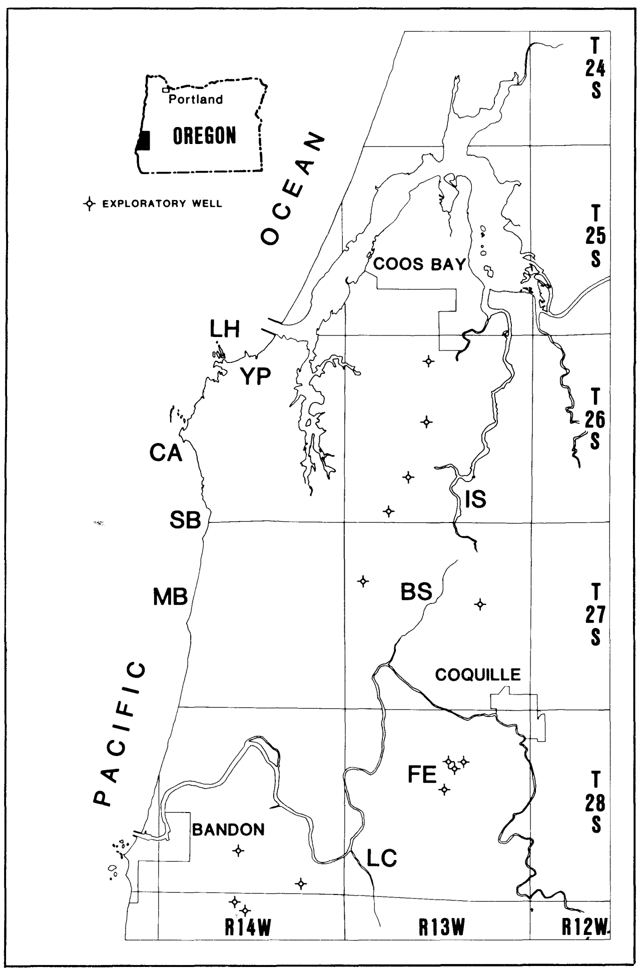

Figure 1. Index map of study area. LH = Cape Arago lighthouse; YP = Yoakam Point; CA = Cape Arago; SB = Sacchi Beach; MB = Merchants Beach; IS = Isthmus Slough; BS = Beaver Slough; FE = Fat Elk; LC = Lampa Creek.

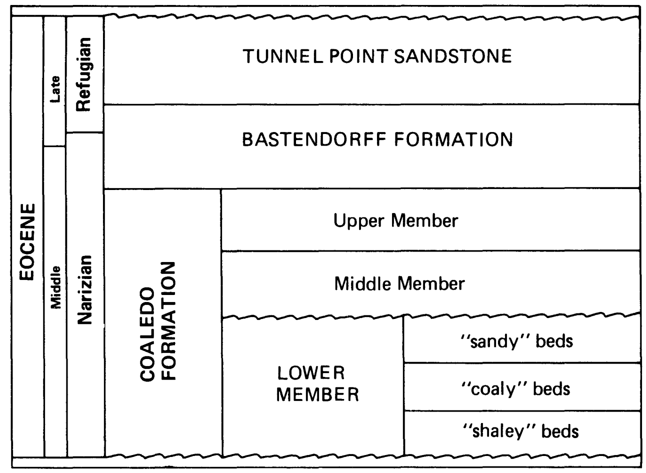

Figure 2. Stratigraphic chart for the Coaledo Formation, Coos Bay basin, Oregon.

The base of the Coaledo has been debated over the years. At Cape Arago, 1,700 ft of lower Coaledo sandstone rests on 650 ft of mudstone and shale. The base of the argillaceous sequence is concealed by faulting. Some authors have included the shaley beds within the lower Coaledo (Baldwin, 1966, 1974; Baldwin and Beaulieu, 1973; Dott, 1966). Other workers have considered the base of the Coaledo to be the base of the sandstones and have assigned the underlying beds to the Pulaski (Turner, 1938), Umpqua (Allen and Baldwin, 1944), Arago (Weaver, 1945), Flournoy (Baldwin, 1975), and Elkton Formations (Rooth, 1974; Ryberg, 1978). This writer believes that these shaley beds correlate with similar rocks which are found inland in the subsurface and which appear to be a part of the lower Coaledo.

Coals are present in both the upper and lower members of the Coaledo. Lower Coaledo coals are not developed along the coast at Cape Arago; however, 2 mi south of the Cape near Sacchi Beach, two thin coals are exposed. Eastward in the subsurface, the coaly beds thicken dramatically. In the central part of the basin, the lower Coaledo coaly beds have a gross thickness exceeding 2,100 ft.

The lower Coaledo sandstones exposed along the coast are continuous inland to the central part of the basin, where 1,100 ft of inner neritic and brackish-water sandstones are present above the coaly beds.

Up until this time, the Coaledo Formation was thought to have been deposited in an area of relatively sustained sedimentation. Dipmeter data from drill holes, however, suggest the existence of an unconformity between the lower Coaledo and overlying members inland from the present-day coast (Figure 4).

The writer wishes to thank Northwest Exploration Company of Denver, Colorado, for permitting the presentation of

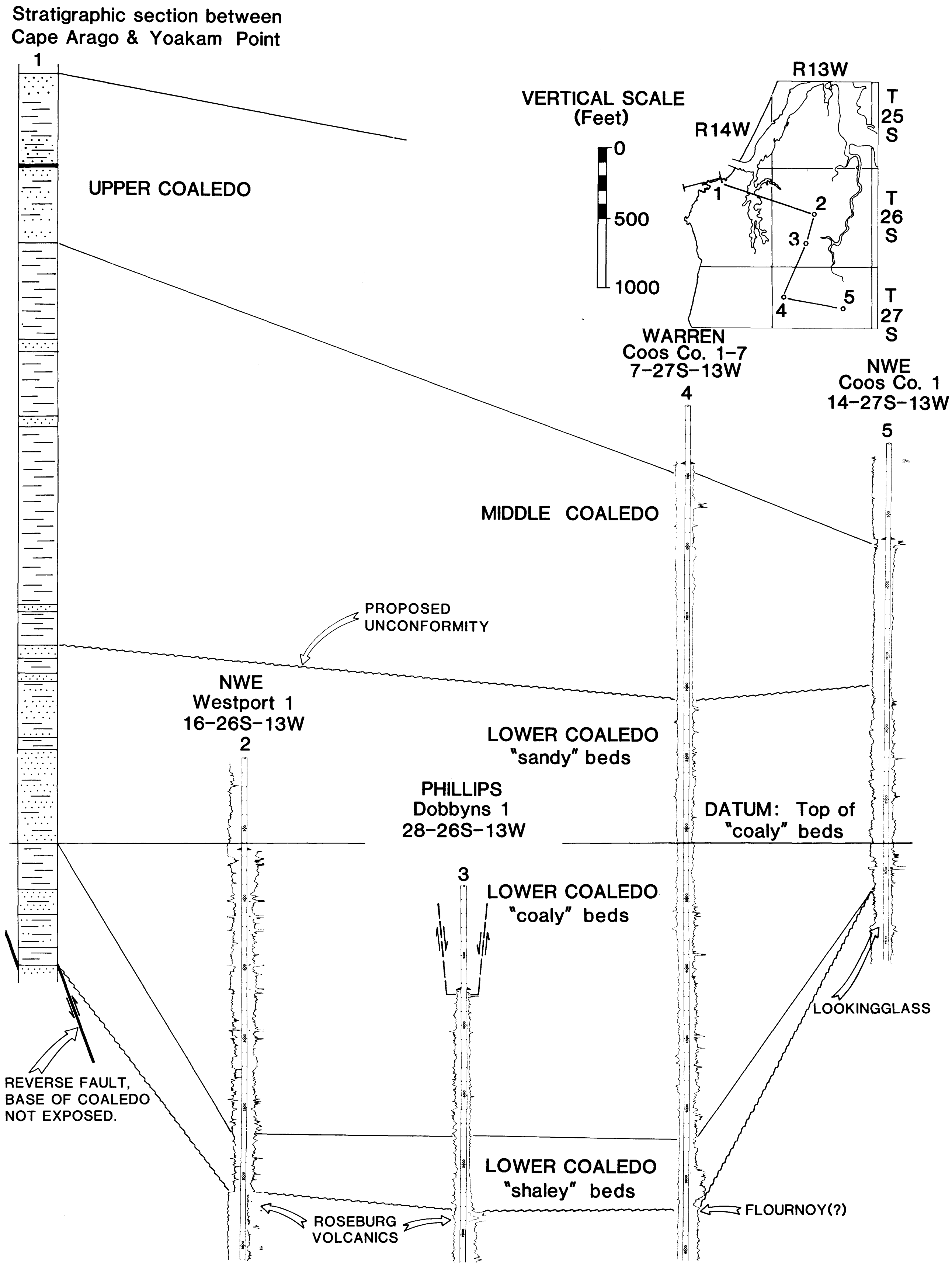

Figure 3. Subsurface stratigraphic correlations of the Coaledo Formation, Coos Bay basin, Oregon.

Table 1. *Locations of exploratory wells mentioned in text.*

NWE Westport 1	SW SE Sec. 16, T26S R13W
PHILLIPS Dobbyns 1	NW SW Sec. 28, T26S R13W
WARREN Coos Co. 1-7	SW SE Sec. 7, T27S R13W
NWE Coos Co. 1	NE SW Sec. 14, T27S R13W
NWE Fat Elk 1	NW SW Sec. 15, T28S R13W

these data. Subsurface data are essential to geological understanding in structurally and stratigraphically complex areas, yet too often such data have been unavailable in the Pacific Northwest. The writer also wishes to thank Ewart M. Baldwin for reviewing the manuscript.

AGE AND CORRELATION

An abundance of paleontological data is available from the Coaledo Formation (Detling, 1946; Cushman and others, 1947a,b; Bird, 1967; Rooth, 1974; McKeel, 1980). The unit is endowed with a diverse faunal assemblage. The microfauna indicates that the entire Coaledo correlates with the benthonic foraminiferal Narizian Stage of Mallory (1959). Traditionally, the Narizian Stage has been regarded by West Coast workers as late Eocene in age. More recently the Narizian Stage has come to be regarded as middle Eocene in age (Poore, 1980).

The Coaledo is but one of several contemporaneously deposited stratigraphic units in the Pacific Northwest. Correlative units include the Spencer Formation in the Willamette Valley and the Cowlitz Formation in northwestern Oregon and southwestern Washington.

PRE-COALEDO UNCONFORMITY

Allen and Baldwin (1944) suggested that a regional unconformity existed at the base of the Coaledo Formation. Overwhelming evidence for such an unconformity can be cited today. The most striking hiatus occurs in a small outcrop in the town of Bandon. Lower Coaledo sediments are in juxtaposition with the Jurassic Otter Point Formation (Link, 1970). Less striking, the Westport 1 and Dobbyns 1 wells encountered lower Coaledo sediments resting on the Paleocene Roseburg volcanics. In the NWE Coos County 1 well, the Coaledo is underlain by the lower Eocene Lookingglass Formation. In the NWE Fat Elk 1 well and numerous outcrops east of Coos Bay, the Coaledo overlies the lower middle Eocene Flournoy Formation.

STRATIGRAPHY

Lower Coaledo

Within the lower member of the Coaledo Formation, three basin-wide informal stratigraphic subdivisions can be recognized. They are, in ascending order, the shaley beds, the coaly beds, and the sandy beds (Figures 2 and 3).

Shaley beds: The shaley beds crop out in North and South Coves at Cape Arago, at Sacchi Beach, and at Merchants Beach. The top of the shaley beds at the coast is considered to be the base of the first overlying massive sandstone. The shaley beds, as described in the introduction, have been included by some authors in various other formations. Inland in the subsurface, the unit is recognized in the Westport 1, Dobbyns 1, and Warren Coos County 1-7 wells, where its thickness is 426, 530, and 500 ft, respectively. The microfauna of the shaley beds in the above three wells and at the Merchants Beach locality is Narizian (Bird, 1967; McKeel, 1980, and 1980, personal communication). The fauna described from the Sacchi Beach locality has both Narizian and Ulatisian affinities (Bird, 1967). The microfauna of North and South Coves is indeterminate with respect to age (Rooth, 1974). The fauna of the shaley beds in the Dobbyns 1 well appears to represent deposition in a cold-water, outer neritic environment (McKeel, 1980). Lithologically, the shaley beds consist of shale and mudstone, with lesser amounts of fine-grained sandstone and laminated siltstone. In the coastal outcrops, the shaley beds also contain spectacular channels. Erratic dipmeter attitudes in the shaley beds in the Warren Coos County 1-7 well may be indicative of similar channeling inland.

Coaly beds: The coaly beds of the lower Coaledo are not particularly well developed at Cape Arago, consisting of only a few thin carbonaceous lenses. Two mi south of the Cape near Sacchi Beach, the coaly beds are more evident. Lower Coaledo coals were mined inland at Lampa Creek as well as at several other localities. A 420-ft-thick coaly section along Lampa Creek contains seven individual coal beds (Allen and Baldwin, 1944). The coaly beds thicken eastward from the coast. In the Westport 1 and Warren Coos County 1-7 wells, the coaly beds have a thickness of 1,880 and 2,115 ft, respectively. The Dobbyns 1 well, drilled in 1944, is somewhat enigmatic since the coaly beds are only about 1,020 ft thick. Marginal marine rocks are reported between 450 and 650 ft in the well (McKeel, 1980). It is believed that the well cut a normal fault at 779 ft (the top of the coaly beds) that shortens the coaly section. The NWE Fat Elk 1 well began drilling in the coaly beds and encountered 840 ft of coal-bearing section before topping lower middle Eocene sandstones. The NWE Coos County 1 penetrated 305 ft of coal-bearing section.

The top of the coaly beds is recognized by the transition from coal-bearing nonmarine sediments to overlying marginal marine sediments. In the Westport 1 and the Warren Coos County 1-7 wells, the transition is also marked by the occurrence of a very coarse-grained, conglomeratic sandstone containing volcanic pebbles. The rocks immediately above the coaly beds in the Westport 1 and and NWE Coos County 1 wells contain a very shallow water fauna consisting of the foraminiferal genus *Elphidium* plus gastropod fragments and sponge spicules. In the central part of the basin, the coaly beds contain up to ten individual coal beds plus numerous thin carbonaceous zones. Electrical logs indicate the individual coal beds range between 2 and 10 ft in thickness.

Sandy beds: The sandy beds of the lower Coaledo are best exposed in the sea cliffs between Cape Arago and the Cape Arago lighthouse. Ryberg (1978) measured 1,365 ft of predominantly fine- to medium-grained, cross-bedded, and laminated sandstone along the coast. In the Warren Coos County 1-7 and the NWE Coos County 1 wells, the thickness of the sandy beds is 1,010 and 1,130 ft, respectively. Lithologically, the top of the sandy beds in both outcrop and the subsurface is abrupt. Faunally, the change is also distinct. The

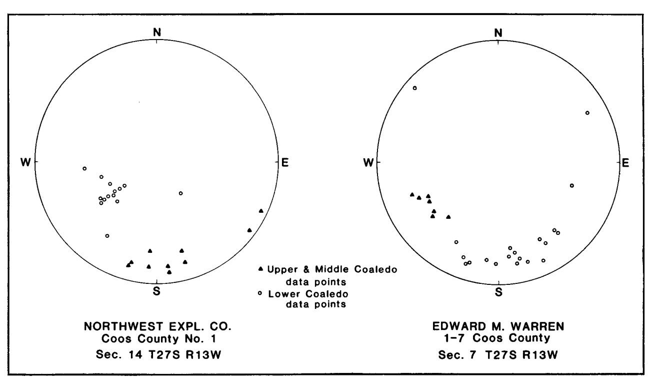

Figure 4. Stereographic plot on lower hemisphere of dipmeter attitudes.

top of the lower Coaledo sandy beds contains inner neritic to brackish-water forms, while the overlying middle Coaledo contains outer neritic to upper bathyal forms.

Middle Coaledo

The middle member of the Coaledo Formation is exposed at the coast between Yoakam Point and the Cape Arago lighthouse. The unit consists of 2,710 ft of thinly bedded, dark-gray mudstone and siltstone (Ryberg, 1978). The middle Coaledo thins eastward. Both the Warren Coos County 1-7 and the NWE Coos County 1 wells penetrated the unit in its entirety. In the wells, the observed thickness was 1,605 and 970 ft, respectively. The middle Coaledo microfauna present in the Coos County 1 well indicates a very rapid transgressive phase to middle bathyal depths, followed by a much slower regressive phase to middle neritic depths. This suggests the middle Coaledo shoreline at one time may have been a considerable distance eastward of the present-day outcrop limits.

Upper Coaledo

Only one oil and gas test well has penetrated a significant amount of the upper Coaledo. The NWE Coos County 1 cut 710 ft of upper Coaledo before reaching the middle member. Fifteen upper Coaledo coal core holes have been described from the Isthmus Slough-Beaver Slough area south of Coos Bay (Duncan, 1953). By correlating the deepest observed coals in the core holes with the deepest upper Coaledo coals encountered in the Coos County 1 well, a composite stratigraphic section can be extrapolated for the upper Coaledo along the eastern side of the basin. Core hole 7-10 (SW ¼ sec. 10, T. 27 S., R. 13 W.) appears to have penetrated 160 ft of Bastendorff Formation before reaching the Coaledo, providing an upper limit to the composite stratigraphic section. The thickness of the upper Coaledo in the eastern part of the basin is about 2,000 ft. This is considerably thicker than the 1,280 ft measured at Yoakam Point on the coast (Ryberg, 1978). There is only one coal bed present at Yoakam Point, while inland there are up to twelve individual coal beds. The westward thinning of the upper Coaledo, the decrease in number of coals, and the complementary westward increase in thickness of the middle Coaledo suggest the middle and upper members of the Coaledo are different facies of the same regressive depositional cycle.

LOWER/MIDDLE COALEDO UNCONFORMITY

In the coastal section near the Cape Arago lighthouse, the lower and middle members of the Coaledo appear to be conformable. Between the two units, however, there is an abrupt change in paleobathymetry, suggesting substantial vertical movement during Coaledo deposition (Rooth, 1974). Inland in the subsurface, there is evidence for an angular unconformity between the two members. Figure 4 is a stereographic plot of dip attitudes from the two wells for which dipmeter data are available. In both wells, the upper- and middle-member data points fall in one cluster, while the lower-member data points fall in a second cluster. While data from only two wells are not conclusive, there is other supporting evidence.

At Fat Elk, 2 mi southwest of the town of Coquille, surface mapping (Baldwin and Beaulieu, 1973) indicates an anticline cored by lower Coaledo and flanked by middle and upper Coaledo. Drilled on the crest of the structure, the NWE Fat Elk 1 well encountered only 840 ft of lower Coaledo, and then only the coaly beds. The sandy beds are not evident on the surface flanks of the structure. The Fat Elk anticline possibly was growing during Coaledo time, resulting in nondeposition of the lower Coaledo shaley beds and either truncation or nondeposition of the lower Coaledo sandy beds.

All three members of the Coaledo Formation are mappable separately in the western and southern portions of the basin. East of Coos Bay, it has been necessary to map the Coaledo as a single unit (Baldwin and Beaulieu, 1973), due, in part, to the eastward pinch out of the middle Coaledo shale and mudstone marker beds and possibly to truncation and onlap of the lower Coaledo by the middle and upper members. The Coaledo sandstone outcrops exposed east of Coos Bay may be entirely upper Coaledo.

CONCLUSIONS

The Coos Bay basin is a sedimentary basin in the true sense, with subsidence concurrent with sedimentation. The frequently studied coastal Coaledo outcrops on the western side of the basin are not representative of the entire formation. The basin axis and thickest sedimentary section appear to be east of the present-day coastline.

The lower member of the Coaledo has been subdivided into three informal units recognizable in the subsurface and in outcrop. In ascending order they are the shaley beds, the coaly beds, and the sandy beds.

The Coaledo Formation represents two predominantly regressive episodes of sedimentation separated by an unconformity. The lower Coaledo was deposited during the first episode, and the middle and upper members were deposited during the second. Perhaps further investigations will reveal an unconformity between the upper Coaledo and overlying Bastendorff Formation, with the Bastendorff and Tunnel Point sandstone representing a third sedimentary episode.

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(Coaledo Formation, *continued on p. 82)*

Finding formations fit for firing

by Ralph S. Mason, former State Geologist

The practice of ceramics has always depended on two basic elements: clay and fuel. The art and the industry of ceramics were born when primitive fire builders discovered that the clay right under their campfires not only turned red but became exceedingly hard. In the centuries that followed this important discovery, the use of fired clay increased and proliferated steadily throughout most of the world.

To be economically viable, clay working must be conducted at a place where there is a source of easily dug clay and a relatively cheap source of fuel. Modern improvements in transportation, both for bulk materials such as clay and for energy such as gas, oil, coal, and electricity, have blurred this historic relationship somewhat, but the low unit value of raw clay still greatly restricts the distance it can be moved from pit to kiln. It is mainly for such economic reasons that history, even pre-history, is firmly on the side of the craft potter who finds and digs his own clay.

Two hundred years ago, itinerant craft potters supplied households with ware made from clay found nearby and fired with wood cut at the site. By and large, settlements tended to locate near streams which provided a ready means of transportation in a land devoid of good roads. The flood plains on which the buildings were erected also supplied clay deposits, composed of clay particles that had been transported and deposited by water. These clays were rather of the common type, but they were readily available; the crude and not very durable wear produced from them was in character with the rough living conditions of the times.

The early-day potter rarely upgraded the clay he dug, since he had little equipment for doing so, and the market was content with the unbeneficiated product. Modern craft potters, however, have a variety of methods at their disposal for improving raw clays and glaze materials. Treatment may include crushing and screening, blunging and decantation, magnetic separation, and blending. But even today, some potters prefer to work with a low-grade clay and to produce ware of refined quality just by applying their skills.

The modern craft potter who wants to dig his own clay has both advantages and disadvantages over his earlier colleagues. On the plus side, the potter has access to a much wider area to look for suitable material, thanks to good roads and the automobile. He also has a great deal of information available in the form of reports and maps, helping him to winnow the potentially good sites from the poor ones. Another plus is a wide choice of digging and drilling equipment which can take much of the drudgery out of searching for and mining the clay.

The disadvantages of digging clay for your own pots pretty much center on the fact that most potters live and work in populated areas where there are many restrictions to prospecting and mining. With patience and effort, however, a potter can locate areas where there is not only clay but also no serious prohibition to removing it. One other factor must be considered: Digging clay, even with the help of mechanical equipment, can be rather strenuous, and a careful assessment of one's physical capabilities should be made.

Populated areas have one feature that can actually help in the search for clay: holes. Civilized countries can almost be rated as to their level of development by the size and number of holes they create. Here is a sampling of holes and excavations that can aid a potter: post holes, power-pole holes, basements, road cuts, wells, graves, and ditches. Road cuts generally top the list in being useful, since we have miles of them and the access, in most cases, couldn't be better. The material that comes out of such holes is an excellent indicator of what lies below the surface. If the spoil pile beside a hole looks interesting, grab a sample and run a few field tests, like making a ball and a snake. If these look good, try gritting some material between your teeth. Your teeth, when they are your natural ones, are remarkably sensitive to particle sizes. (The modern porcelain substitute, unfortunately, is quite insensitive to another clay's properties.) A propane torch can be used to make a rough firing test for color and behavior at high temperatures.

Clays passing these tests should be collected and given further examination in the studio. Be sure to keep good records as to where you took your samples; attach labels, tags, or other markings.

There is no sense in looking for something that you know little about. "Know before you go," is excellent advice. Hunting for clay is much like hunting elephants—just as you look for elephants in elephant country, so you look for clay in "clay country." Therefore, before you go off into the countryside looking for some clay, get all the information you possibly can. Check out reports on clay deposits, soil types, and geology; obtain topographic, soil, and geologic maps. If you are unfamiliar with the various clay-forming processes, read a college-level physical geology text on the subject.

Here is a suggested program for obtaining the information you will need: First, determine how far afield you plan on prospecting. Second, buy some detailed maps of the areas you have decided on. The topographic maps published by the U.S. Geological Survey are excellent. They show roads, streams, elevations (by means of contour lines), buildings, dams, power lines, and a land net which shows the legal divisions into sections, townships, and ranges. These maps are sold at many stationery stores, outdoor recreation shops, and state departments of geology. Soil maps published by the U.S. Soil Conservation Service usually cover an entire county and show the distribution of the surface soils, describing each type. County agents and, sometimes, libraries have these maps. Third, go to the appropriate state geology department or state university library and read any reports they have on the geology of your region. If you are unfamiliar with some of the terms used in the publications, pick up a geology text at your bookstore or at the college co-op.

Proper tools are a must for any successful prospecting trip. Figure 1 shows a suggested list of items to take. Quite possibly some of them will not be needed for your work, and again you may find some additional tools necessary. After a trip or two, you can trim or expand your equipment to fit your needs. Most of the items shown in the illustration can be obtained at hardware stores, particularly shops serving farming communities. Be sure to take your Good Manners with you; they may be the most important tool in the sack.

You are finally ready for your first clay-prospecting trip. You have read reports, have bought some maps and tools, and are itching to go find a deposit of good clay. Now, book learning is essential, but a good practical example of just what a deposit looks like is mighty helpful. A visit to a commercial clay plant in the general area of your interest could be most instructive. There were literally hundreds of clay pits in operation in Oregon and Washington fifty years ago, and many of

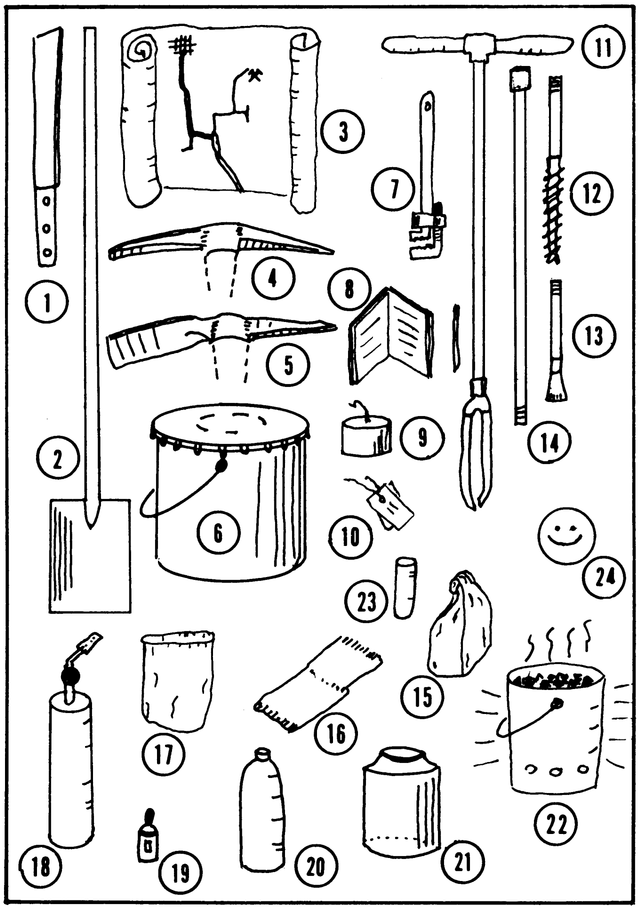

Figure 1. Typical equipment used for clay prospecting and field testing. (1) Corn knife. (2) Long-handled shovel. (3) Map. (4) Clay pick. (5) Mattock. (6) Plastic bucket with lid. (7) Stillson wrench. (8) Notebook, pencil. (9) String in container. (10) Labels. (11) Iwan-type soil auger. (12) Screw auger. (13) Chopping bit. (14) Extra length of pipe, 36 inches. (15) Sack lunch. (16) Old rags or towel. (17) Cloth or plastic sacks. (18) Propane burner. (19) Dropper bottle with 1:1 HCl acid. (20) Water bottle or canteen. (21) Glass gallon jar, wide-mouth. (22) Old bucket, hibachi, or barbeque. (23) Test tube. (24) Good Manners.

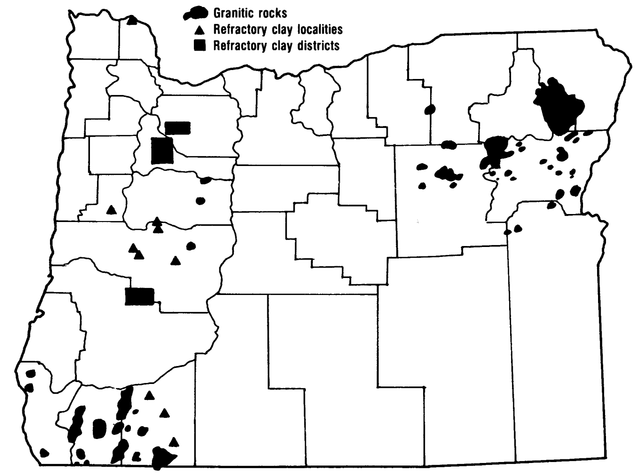

Figure 2. Areas of intrusive rocks and refractory clay districts and localities in Oregon.

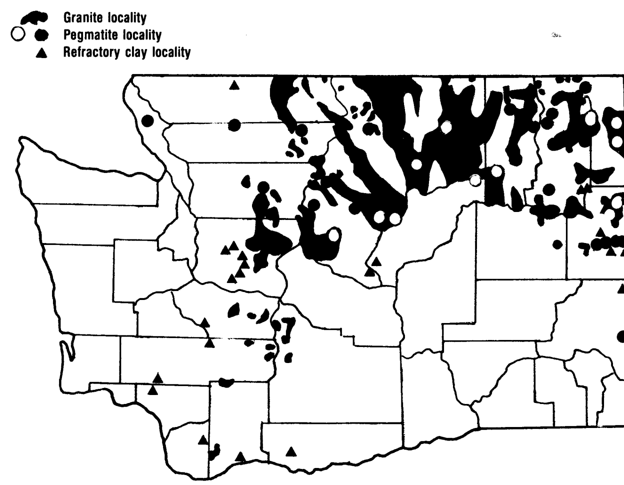

Figure 3. Areas of intrusive rocks and refractory clays in Washington.

these were located in bottom land that was frequently flooded. Records of these operations are usually available in reports issued by either state, provincial, or federal agencies. Unfortunately, quite a few brick and tile plants have succumbed in recent years, but some of their clay pits are still accessible. Take a good look at the clay formation, the overburden, and the general setting in which the deposit is located. Chances are that similar conditions extend away from the pit and that some road cut in the vicinity can yield satisfactory clay.

The removal of some clay from such a spot should cause no problems, since cuts tend to slough down onto the road or drain ditch, and the clay removal does no harm. If in doubt about the propriety of digging along some road, you should talk to the roadmaster or his equivalent. For very small amounts of clay, it is better to let sleeping bureaucrats lie. Sometimes it is necessary to drill to get your samples. The Iwan-type soil auger works well in this service. Wear a sweatshirt or similar garment when drilling, since the auger handles are death on clothing with buttons. Also, do not keep anything in any pockets above your waist—the pocket contents seem to be attracted to the hole you are drilling, and retrieval can be difficult.

Craft potters who are looking for clays of some higher grade, with a higher firing range and lighter color, may be interested in the refractory clay deposits scattered around the countryside, many of which are of the residual type. Unlike the transported clay deposits found on flood plains and along streams, the residual clays are directly associated with weathered granite and pegmatite and tend to occur in hilly or mountainous terranes.

In Oregon, granitic outcrops are found in the southwestern and northeastern corners of the state, somewhat removed from the population concentrations. In Washington, these same rock formations are more favorably located, extending across large areas of the northern half of the state. Figure 2 shows the distribution of the principal refractory clay localities and districts in Oregon. Also shown are the generalized areas of granitic rocks which, if sufficiently weathered, may form clay deposits of better-than-average quality. A report on the refractory clays of western Oregon by Wilson and Treasher (1938) is listed in the bibliography. Two somewhat similar publications by Wilson (1923) and Wilson and Goodspeed (1934) are also listed. Figure 3 shows the generalized localities for refractory clays, pegmatites, and granite in Washington. Before starting out for those granite-studded hills, please be advised that not all granites are weathered, and not all weathered granites are suitable for ceramic uses.

Finally, let me reiterate one bit of advice mentioned above: When you go out prospecting be sure and take your Good Manners with you. Good Manners open many doors that otherwise might be slammed tightly shut. Every square inch of the countryside is owned by somebody, and that somebody might take a very strong objection to your presence unless you conduct yourself most circumspectly. Remember that a low-iron clay is far less important than a lead-free body.

SELECTED REFERENCES TO OREGON AND WASHINGTON CLAYS

Allen, J.E., and Mason, R.S., 1949, Brick and tile industry in Oregon: Oregon Department of Geology and Mineral Industries Short Paper 19, 28 p.

Kelly, H.J., Strandberg, K.G., and Mueller, J.I., 1956, Ceramic industry development and raw-material resources of Oregon, Washington, Idaho, and Montana: U.S. Bureau of Mines Information Circular 7752, 77 p.

Shedd, S., 1910, The clays of the State of Washington, their geology, mineralogy, and technology: Pullman, Wash., State College of Washington, 341 p.

Wilson, H., 1923, The clays and shales of Washington, their technology and uses: Seattle, Wash., University of Washington, Engineering Experiment Station Series Bulletin 18, 224 p.

Wilson, H., and Goodspeed, G.E., 1934, Kaolin and china clay in the Pacific Northwest: Seattle, Wash., University of Washington, Engineering Experiment Station Series Bulletin 76, 184 p.

Wilson, H., and Treasher, R.C., 1938, Preliminary report of some of the refractory clays of western Oregon: Oregon Department of Geology and Mineral Industries Bulletin 6, 93 p.

For further references the reader may consult the several bibliographies in Ralph S. Mason's recent book, *Native Clays and Glazes for North American Potters. A Manual for the Utilization of Local Clay and Glaze Materials*, published in Portland by Timber Press (see review in *Oregon Geology* of February this year). □

Daylight fireball, December 16, 1981

At 11:06 a.m., Pacific Standard Time, December 16, 1981, a daylight fireball occurred over northwest Oregon and southwest Washington. The fireball was seen from Seattle, Washington, on the north, to Lincoln City, Oregon, on the south, and as far east as Portland, Oregon. This report is based on 21 sightings reported to the author.

The meteoroid apparently entered the atmosphere over the Cascade Mountains of southern Washington, coming down at an angle of 15° and heading west-southwest. Most observers reported the object to be about one-fourth the size of a full moon, with a flight time of 1½ to 5 seconds. The color of the fireball was blue-white to blue-green, with a long tail that changed color from yellow to orange to red. There were four reports of a vapor trail and one report of the fireball breaking up. There were two reports of a whistling sound but no reports of a sonic boom.

Since observers on the Oregon coast saw the fireball heading to the west, and since no sonic booms were reported by observers, it must be assumed that if the fireball produced any meteorites, they landed in the Pacific Ocean, where recovery is almost impossible.

Daylight fireballs are uncommon but seem to occur over Oregon once or twice a year. Readers sighting such phenomena are asked to contact the author at Cleveland High School, phone (503) 233-6441.

—*Dick Pugh, Science Teacher, Cleveland High School, 3400 SE 26th, Portland, OR 97202*

Volcanic hazards assessed for California's Long Valley-Mono Lake area

Future volcanic eruptions of moderate size, similar to those that have occurred frequently in the geologic past in the Long Valley-Mono Lake area, California, could seriously affect communities within about 50 mi of the area, according to a preliminary hazards assessment released by the U.S. Geological Survey (USGS), Department of the Interior. The area is just east of Yosemite National Park in east-central California. USGS scientists emphasized that no one was issuing a specific prediction of an immediate eruption in the area. No eruptions are known to have occurred within the past several centuries of historic records. Recent changes in earthquake patterns and other events, however, prompted the USGS to issue a notice of potential volcanic hazard for the Mammoth Lakes area, California, on May 26, 1982. This is the lowest of three levels of formal concern that can be issued by the earth science agency.

The hazards-assessment report was prepared in conjunction with the notice and was patterned after more detailed assessments that have been conducted by the USGS in other volcanic areas, such as Mount St. Helens, Washington; Mount Shasta, California; and Mount Hood, Oregon. The report, USGS Open-File Report 82-583, is titled *Preliminary Assessment of Potential Volcanic Hazards in the Long Valley-Mono Lake Area, East-Central California and Southwestern Nevada* and contains information on the possible kinds, scales, and consequences of eruptions that might be expected.

The volcanic-hazards notice was issued as a result of recently discovered intermittent swarms of earthquakes and spasmodic tremor and the outbreak of new steam vents in the area. Among other conclusions, these recent events suggest that a tongue of molten rock several miles below the land surface may be moving slowly upward.

The USGS notice states, "The ultimate consequences of this activity are uncertain. It is quite possible that no eruption will occur and that the magma will cool and solidify to form an intrusion at depth. If an eruption does occur, the possible consequences vary greatly in severity. The kinds of activity that might be expected include phreatic (steam) explosions, pumice and ash falls, pyroclastic flows, mudflows, and extrusion of a lava dome."

C. Dan Miller, a USGS geologist in Denver, Colorado, and principal author of the hazard assessment and an accompanying map, emphasized that the report is preliminary and based on the limited studies and data currently available. He said studies are now underway to provide a more comprehensive volcanic-hazard assessment for the area.

According to the preliminary hazards assessment, an explosive volcanic eruption of moderate volume in the Long Valley-Mono Lake area could send pyroclastic flows of hot-rock debris and gases surging over the land surface to distances of up to 12 mi from where the volcano vents. Such an eruption could also produce ash clouds that would deposit up to about 8 in. of ash at distances of about 20 mi from a vent and 2 in. of ash at distances of up to 50 mi.

Geologic studies show that volcanic eruptions of widely varying magnitude have occurred in the Long Valley-Mono Lake region during the last one million years, with the most recent eruption occurring sometime within the past 400 years. Miller said more eruptions can be expected in the future and that recent events indicate that an eruption could occur in the near future.

The USGS report and map concentrate on volcanic haz-

(**Volcanic hazards**, *continued on p. 82)*

OIL AND GAS NEWS

Columbia County

Reichhold Energy Corporation continues to drill in the Mist Gas Field after a successful redrill of Columbia County 13-1 in May. The most recent well is Columbia County 43-5, located in sec. 5, T. 6 N., R. 5 W., 1.5 mi from the nearest production. The total depth is 3,099 ft, but results from the logging of the well are not yet available.

Clatsop County

Exploration for oil and gas is once again taking place in Clatsop County after a hiatus of several months. Oregon Natural Gas Development Corp. is drilling Patton 32-9, a follow-up to its Johnson 33-33 well of last year, a dry hole. The new location is sec. 9, T. 7 N., R. 8 W., 3 mi east of Olney. ROVOR Drilling is the contractor, using the same rig that drilled the Johnson location, this time drilling to a proposed depth of 8,000 ft.

Douglas County

Florida Exploration Company continues to drill FEC 1-4 near the town of Drain. Difficulty with casing has slowed progress, with present depth of about 3,000 ft.

Malheur County

The Z & S Construction Company location reported on last month has been drilled to a total depth of 4,745 ft and abandoned as a dry hole. The company has not announced plans for further drilling in the county.

Northwest Association of Petroleum Landmen formed

On June 11, about 75 oil industry personnel, mostly landmen, met at Northwest Natural Gas Company headquarters in Portland for election of officers and adoption of bylaws. They were joined by Calvin Blue and Harry Sprinkle of the American Association of Petroleum Landmen. The elected officers include Kyle Huber, President; Garth Tallman, Vice-President; Ron Hordichok, Secretary; and Judith Hiserote, Treasurer. The Board of Directors consists of Kurt Humphrey, Alf Lausitzen, and Dolores Yates.

The purposes of the organization are to promote communication between members of the Association, government, community, and industry regarding energy issues; to educate the public about energy issues and about landmen; and to further the education of the petroleum landman.

There are over 100 members in this new organization.

Recent permits

Permit no.	Operator, well, API	Location	Status
217	Reichhold Energy Corp. Libel 21-15 009-00103	NW¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Location

□

(Coaledo Formation, *continued from p. 78)*

Ryberg, P.T., 1978, Lithofacies and depositional environments of the Coaledo Formation, Coos County, Oregon: Eugene, Oreg., University of Oregon master's thesis, 159 p.

Turner, F.E., 1938, Stratigraphy and Mollusca of the Eocene of western Oregon: Geological Society of America Special Paper 10, 130 p.

Weaver, C.E., 1945, Stratigraphy and paleontology of the Tertiary formations at Coos Bay, Oregon: Seattle, Wash., University of Washington Publications in Geology, v. 6, no. 2, p. 31-62. □

Last chance at old prices

Because of recent increases in publishing costs and postage, we find it has become necessary to raise the price of a subscription to *Oregon Geology*. Effective August 1, 1982, a one-year subscription to *Oregon Geology* will cost $6, a three-year subscription $15. At the same time, the prices of some of our other publications will be raised to cover the increased cost of mailing. The new prices will be printed on the back cover of the August *Oregon Geology*.

So, if you are thinking of renewing your subscription to *Oregon Geology* or buying some of our publications, July would be a good time to do it. □

Oregon High Desert Museum opens

After five years of planning and development, the Oregon High Desert Museum opened its doors to the public on May 29, 1982. Located 7 mi south of Bend on Highway 97, the museum features exhibits on the land and people of the High Desert, live-animal demonstrations, a forestry learning center, participatory activities for the public, traveling exhibits, outdoor trails, and special programs and classes on a variety of topics.

Summer hours are 9:00 a.m. to 5:00 p.m. daily through September 30. Winter hours are 9:00 a.m. to 4:00 p.m. daily starting October 1. The museum will be open every day except Thanksgiving, Christmas, and New Years Day.

Admission fee is $1 for adults, 50¢ for children 6 to 12 years of age. The museum phone number is (503) 382-4754. □

GSOC luncheon meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

July 16—*Preview of the President's Campout at Bend, Oregon (July 30-August 6)*: by President Ruth Hopson Keen. For more information about the campout, call 222-1430.

August 6—*Show and Tell*: Bring your favorite geologic specimens.

August 20—*Pictures of the President's Campout*: by Clair Stahl.

For additional information about the luncheons, contact Viola L. Oberson, Luncheon Chairwoman, phone (503) 282-3685. □

(Volcanic hazards, *continued from p. 81)*

ards from a possible moderate size explosive eruption with an ejected volume of as much as 0.25 mi³ of material. They also, however, show areas that could be severely affected by a catastrophic eruption similar to one that occurred in Long Valley about 700,000 years ago. That catastrophic eruption produced about 140 mi³ of ash and has not been equaled anywhere in the world during historic times. By comparison, the May 18, 1980, eruption of Mount St. Helens in southwestern Washington ejected only about 0.25 mi³ of ash.

Other authors of the report and map are Dwight R. Crandell, Donal R. Mullineaux and Richard P. Hoblitt, all USGS geologists in Denver, Colorado; and Roy A. Bailey, a geologist at the USGS National Center in Reston, Virginia.

Copies of USGS Open-File Report 82-583 may be purchased from the Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225. Prices are $2.50 for each paper copy and $1 for microfiche. □

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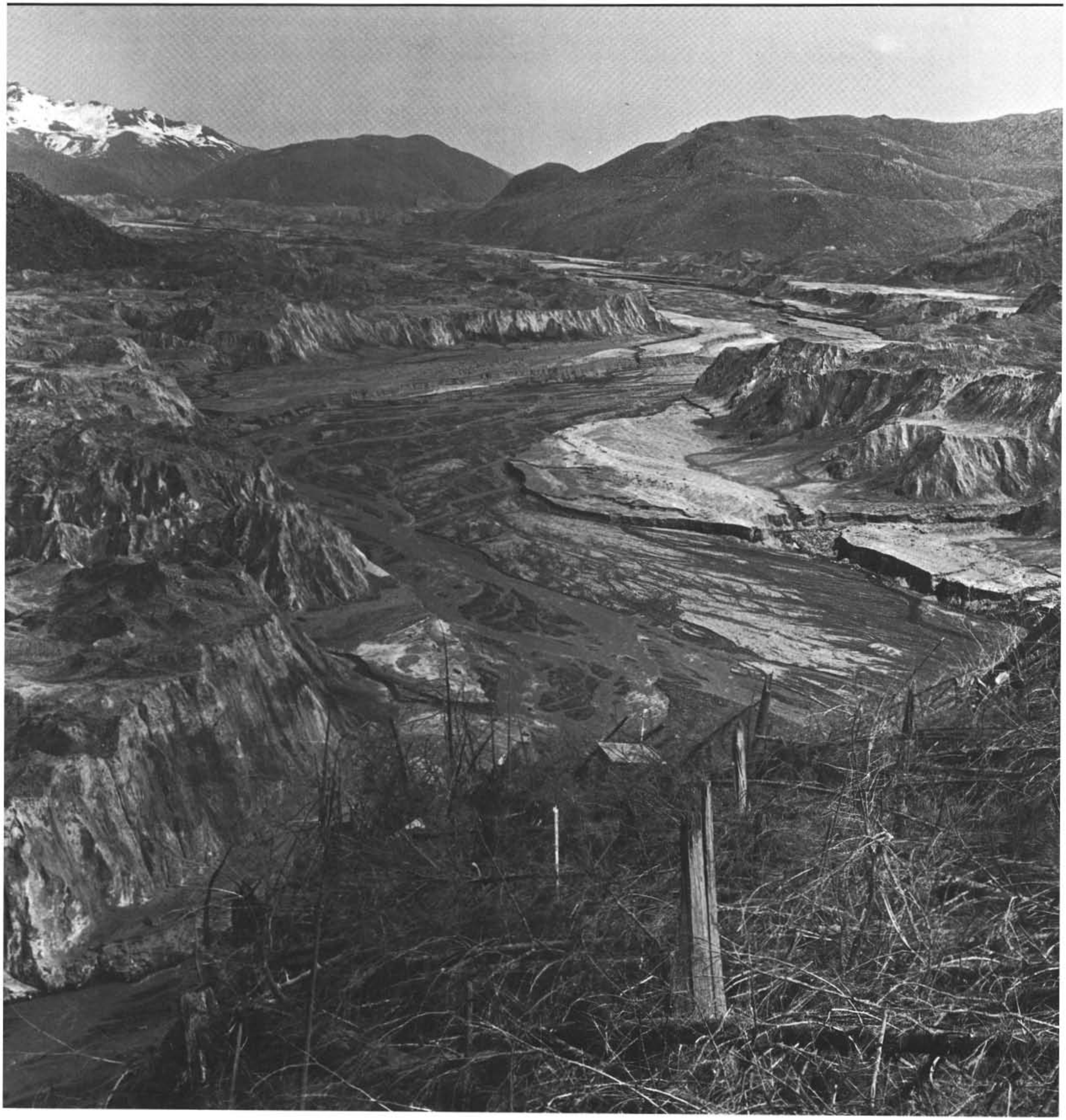

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COVER PHOTO

View from Elk Rock, overlooking the North Fork of the Toutle River, northwest of Mount St. Helens, Washington. Photo shows May 18, 1980, debris avalanche, the North Fork of the Toutle channel, and the March 19, 1982, mudflow in the channel. Field trip guide beginning on next page describes mudflows of both eruptions of Mount St. Helens. (Photo courtesy Lyn Topinka, U.S. Geological Survey, David A. Johnston Cascades Volcano Observatory.)

Department releases new geologic maps

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the publication of two new maps in its Geological Map Series (GMS).

Map GMS-21, *Map Showing the Geology and Geothermal Resources of the Vale East 7½-Minute Quadrangle*, by D.E. Brown, covers an area of about 56 mi² south and east of Vale, eastern Oregon. This multicolored outcrop map is at a scale of 1:24,000 and shows bedrock units as they are actually exposed at the surface. The map delineates nine surficial and bedrock geologic units and the geologic structure of the quadrangle, both on the map and in the accompanying geologic cross section. Also shown are the locations of 38 wells and springs and data for them such as temperature, geothermal gradient, and heat flow.

Map GMS-23, *Geologic Map of the Sheridan Quadrangle, Polk and Yamhill Counties, Oregon*, by M.E. Brownfield, covers the Sheridan 7½-minute quadrangle, which includes the cities of Sheridan and Willamina and straddles the border between Polk and Yamhill Counties, western Oregon. The map shows eight bedrock and surficial geologic units, geologic structure, numerous fossil localities, and a geologic cross section. Also included is a discussion of the stratigraphy, structure, and economic geology of the map area, along with a list of the fossil locations. The geologic investigation of the Sheridan quadrangle was part of a regional stratigraphic study in the northern Oregon Coast Range to assess the potential for oil and gas. While no oil and gas exploration holes have been drilled in the quadrangle so far, significant stratigraphic and paleontologic information obtained in this study indicates that the Yamhill Formation is a potential source rock for petroleum.

Both maps are available from the Portland office of the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201, at a price of $5 each. Orders under $50 require prepayment. □

Lasmanis named State Geologist for Washington

Raymond Lasmanis has been named new State Geologist for the state of Washington, with responsibility for directing the Natural Resources Department's Division of Geology and Earth Resources. This division oversees oil and gas drilling and exploration and surface mining in Washington as well as mapping of the state's geologic resources.

Lasmanis, former assistant secretary and exploration manager with Canadian Superior Ltd., has also worked for Pine Point Mines Ltd. and Cominco American Inc. His 14-year service with Canadian Superior included management of the West End gold production in Idaho and the Tonzona coal project in Alaska.

Lasmanis, who succeeds Ted Livingston, started his new duties on July 14. □

CONTENTS

Mount St. Helens road log: A visit to the lower Toutle and Cowlitz River drainages to observe the sedimentology, transported trees, and other effects of mudflows resulting from the eruptions of May 18, 1980, and March 19, 1982*

by William J. Fritz, Department of Geology, Georgia State University, Atlanta, Georgia 30303;
Lanny H. Fisk, Department of Geological Sciences, Loma Linda University, Riverside, California 92515; and
Sylvia Harrison, Department of Geology, University of Montana, Missoula, Montana 59812

INTRODUCTION

Shortly after the explosive eruption of Mount St. Helens on May 18, 1980, devastating mudflows moved down the Toutle River drainage, into the Cowlitz River, and on to the Columbia, causing widespread braiding due to the high sediment load. These mudflows were then reworked by streams, leaving a record of alluvial volcaniclastic sedimentation. A second series of mudflows that can be seen at stops indicated in this road log was generated by an eruption late on March 19, 1982 (Simon, 1982).

Mudflows were not unexpected and, in fact, had been suggested by Crandell and Mullineaux (1978) as potential hazards from any future eruptions. However, the stream systems most likely to be affected and the general magnitudes of the anticipated flows were matters of conjecture (Cummans, 1981), generating considerable discussion among volcano observers in the weeks immediately preceding the major eruption and following the mountain's initial early warnings.

This road log describes features of mudflows and associated alluvial deposits resulting from the 1980 and 1982 eruptions and follows, in reverse direction, the route of the mudflows, pointing out significant geological features to the participant. At designated stops en route (Figure 1), we have indicated some important sedimentological features, many of which are even now being removed by natural erosion and by the U.S. Army Corps of Engineers as part of their stream stabilization program. Barring near-future mudflows to cover and preserve these features, within only a few years they will undoubtedly be completely destroyed. Thus, due to the ephemeral nature of the mudflow deposits, the extremely high precipitation, large spring run-offs, and the rapid growth and rejuvenation of vegetation, some features described in this road log may not remain for a very long period of time. How-

* Prepared August 1981 and April 1982.

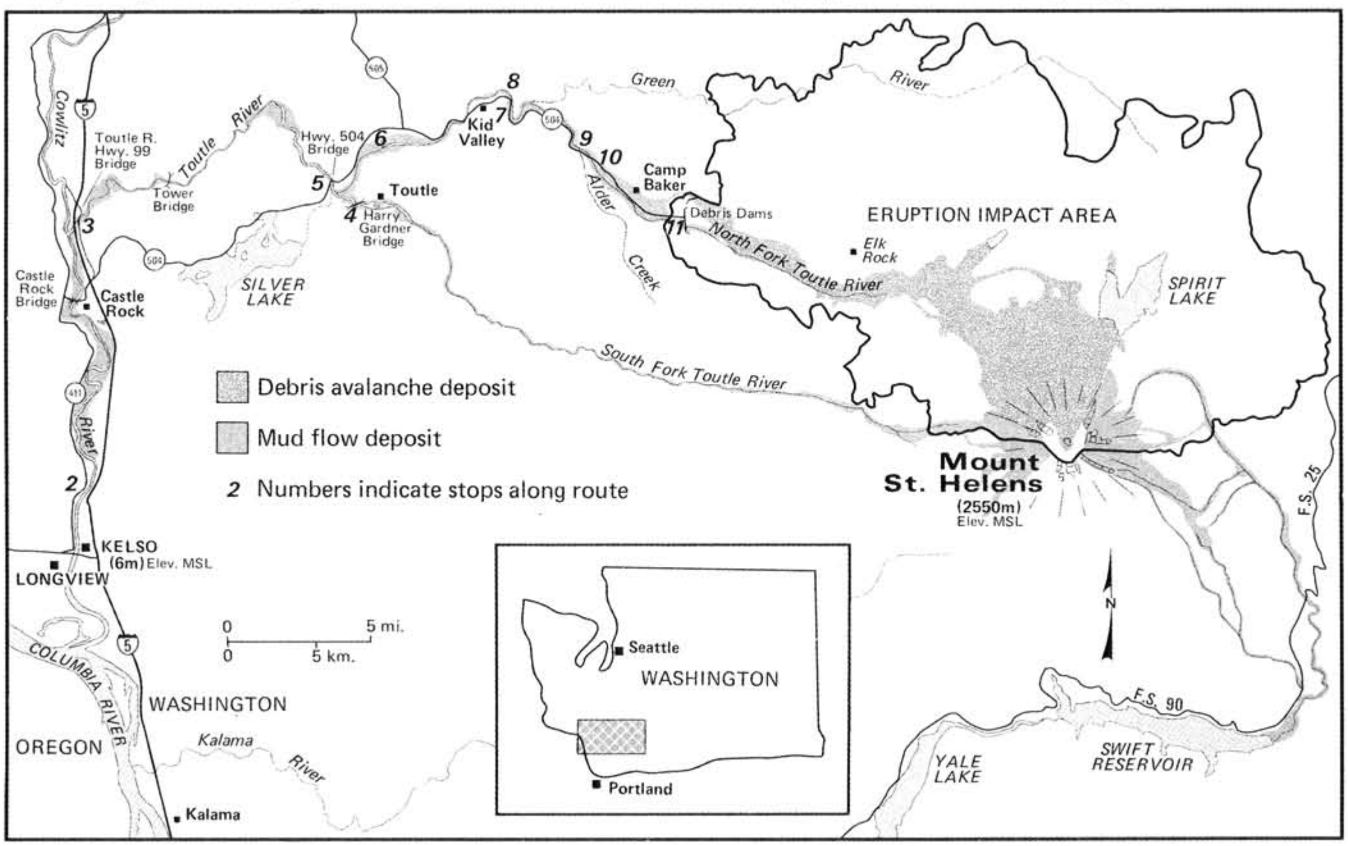

Figure 1. Location map of the Mount St. Helens area showing route taken for this field guide. (Modified from Fritz, 1980, and Cummans, 1981.)

ever, if any features are preserved from Mount St. Helens, they will be these lowland mudflow deposits and not the devastated highlands.

The mudflows produced by eruptions of Mount St. Helens provide a ready modern environment that helps geologists understand volcaniclastic deposition in the geologic record. Some areas in the northwestern United States that contain Tertiary age rocks similar to those described in this road log are the Eocene Absaroka Volcanic Supergroup in the Yellowstone Park region, the Challis Volcanics of central Idaho, and the Clarno volcanic deposits in central Oregon. Emphasis in this road log is thus placed on those features suited for preservation in the record and also on areas that will help in interpreting past environments.

Please notice the constantly changing sedimentary structures while hiking across point bars of the Toutle and Cowlitz Rivers. Some readily observable sedimentary structures include grading, straight-crested ripples, linguoid-lunate ripples, megadunes, antidunes, and tangential cross-bedding.

Another interesting feature is the fining of the mudflow away from the mountain. Along the Cowlitz River, reworked mudflows are composed of well-sorted silt to coarse sand. Upstream, the deposits coarsen to pebbles on the Toutle River and include boulders 1-2 m in diameter upstream from Toutle. The lower portions of the mudflow generally contain grain-supported clasts of several distinct rock types, while those nearer the source area have large boulders supported in a matrix of pebbles and coarse sand. One apparent exception to this fining downstream is the inclusion of pebble pumice lenses in otherwise well-sorted sand. The pumice clasts, due to their low density, were floated and transported by flow conditions that normally are competent to move only silt or sand. In some areas along the route of this road log, small lakes or slack water ponds were produced by overbank flooding. These ponds should be ready sites for preservation of leaves and other plant material.

Also emphasized in our road log are the voluminous quantities of logs, stumps, and plant debris transported by mudflows of both 1980 and 1982. Surprisingly, many of the stumps that were broken short by the blast or by prior logging and that have wide root systems remain upright even after considerable transport along the Toutle and Cowlitz Rivers (Fritz, 1980; Fritz and Moore, 1981). Many of the stumps contain an accumulation of fine rootlets and root-entwined boulders and would be difficult to distinguish, after burial, from the trees buried in place along the rivers. Unlike the short broken stumps, long trees were carried and deposited in large, horizontally oriented log jams.

In providing for some of the historical details in this road log, we are highly dependent on Cummans (1981), whose report we suggest you read before proceeding. You may also find articles by Fritz (1980), Youd and Wilson (1980), Fritz and Moore (1981), and Lombard and others (1981) and maps by the U.S. Geological Survey (1980) and the U.S. Forest Service and others (1981) to be of help. Figure 1 shows the route of this road log. If you wish to follow this road log while driving south from Seattle, drive south on Interstate 5 to Kelso, Washington, take Exit 39 (Highway 4), and enter the road log at the 40.4-mi mark. The majority of the features described here are outside of any controlled zones around the mountain. If you wish to proceed beyond the 83.4-mi comment (Stop 8) into the Red or Blue Zones, please obtain the proper authorization before proceeding.

Please proceed with caution while walking on mudflow surfaces. Many appear deceptively firm but are unstable and muddy due to thixiotropic behavior, meaning that they may turn to a liquid if jarred repeatedly. The more recent the mudflow, the more likely it is to display this behavior.

Note: The boundaries of the Red and Blue Zones may change in the course of time. Readers should also be aware that conditions may be dangerous anywhere around the volcano. Visitors should never approach the area without up-to-date information.

ROAD LOG

Total miles	Increment miles	Comments
00.0		START OF ROAD LOG: Northbound on I-5, at the Oregon-Washington state line in the center of the Interstate Bridge over the Columbia River.
	18.0	
18.0		Cross East Fork of the Lewis River.
	1.6	
19.6		North Fork of the Lewis River. It is interesting to speculate that if the blast of the major eruption had been to the east or south, the entire Lewis River might look like the Toutle River drainage.
	1.4	
21		STOP 1: The visitors center 0.5 mi east of the freeway in Woodland (Highway 503, Exit 21) contains some good photographs of Mount St. Helens. You can purchase the map by U.S. Forest Service and others (1981) here. Note that the round-trip mileage from the freeway is not included in the road log; persons bypassing this stop use the indicated mileage.
	2.5	
23.5		Marine basalts of the upper Eocene Hatchet Formation (probably equivalent to the Goble Volcanic Series of Oregon [Roberts, 1958]) exposed in road cuts on the east side of I-5. This will be the major ridge-forming rock type exposed in road cuts for the next 12-14 mi. McKee (1972) provides an interesting discussion of rocks exposed in this area.
	3.0	
26.5		View of Trojan nuclear power plant to the north.
	5.0	
31.5		Outcrop of Pliocene Troutdale Formation sandstone and conglomerate exposed in a quarry on the east side of I-5. This formation represents deposition by the ancestral Columbia River.
	8.9	
40.4		Take Kelso Exit 39, Highway 4, off I-5 just past bridge over the Coweman River.
	0.5	
40.9		Turn west (left) on Allen Street – State Highway 4. Note Volcano Center and St. Helens World – commercialization of a catastrophe.
	0.2	
41.1		Pile of St. Helens ash dredged out of the Cowlitz River on left. Continue straight at intersection where Highway 4 turns right.
	0.8	
41.9		Bridge over Cowlitz River.
	0.1	
42.0		Turn north (right) on Highway 411. Cowlitz River on the right shows effects of mudflows and subsequent dredging. Transported trees and mudflow deposits from the 1980 and 1982 eruptions can be seen on the east bank.
	0.9	
42.9		Accumulation of transported trees on east bank

Figure 2. Point bar on the lower Cowlitz River at STOP 2. Grassy covered area in the foreground is a vegetated portion of the 1980 mudflow. The point bar is composed of fine-grained sand and silt reworked by the 1982 mudflow. Note the transported stumps and logs.

of river. Note upright transported stump.

1.1

44.0 Lots of transported stumps and logs on a point bar on the east side of the river. Note fine-grained nature (silt and fine sand) of the sediment.

0.1

44.1 Ash and mudflow debris dredged out of the river can be seen in piles on the left.

2.5

46.6 STOP 2: Stop at pullout on east side of Highway 411 at intersection with King Road to the west. Massive dredging operation on the east (right) bank of the Cowlitz River. Note transported upright stumps in the river and a diagonal log just upstream (Figures 2 and 3). Does it stump you as to how they got there? This is a good place to hike down to the river to observe grain size (Figure 4), sedimentary structures, and transported trees from the 1980 and 1982 mudflows. Continue north on Highway 411.

1.7

48.3 Note mudflow deposits in farm fields in this small valley. It is understandable why these people were nervous the afternoon and evening of May 18, 1980!

4.2

52.5 Bridge over Arkansas Creek. Mudflows now vegetated with green grass on the right were initially covered with logs and debris that have since been removed by your U.S. Army Corps of Engineers. Also, the road you are driving on was destroyed by the 1980 mudflow and has been replaced. Most of the green fields in this area are re-vegetated mudflow deposits from the 1980 eruption.

0.7

53.2 Turn east (right) at intersection with Highway P.H. No. 10. Heavy equipment is being used in clean-up operations.

0.3

53.5 Cross Cowlitz River. Enter Castle Rock, Washington, on "A" Street.

0.4

53.9 Turn north (left) on Huntington Avenue.

Figure 3. Upright stump transported by the 1980 mudflow on the lower Cowlitz River at STOP 2. Note fine-grained sediment size.

0.6

54.5 Pull-off on the left. This portion of the road was nearly washed out by the 1982 mudflow. Observe the transported wood on point bars of the Cowlitz River and deposits from both mudflows. The green fields across the river are 1980 mudflows.

0.2

54.7 Turn north on I-5 toward Seattle.

0.5

55.2 Mud-cracked undisturbed swamp filled with water-sedimented ash. This swamp illustrates lacustrine sedimentation in a volcaniclastic terrain. Are we observing fossilization?

1.4

56.6 Bridge of Toutle River. The bare area was covered with trees killed by the hot mudflows and with transported trees. These have since been logged.

0.8

57.4 Take Exit 52—Toutle Park Road.

0.1

57.5 Turn right at stop sign toward Toutle River Viewpoint on Old Pacific Highway.

0.2

Figure 4. Exposure of fine-grained tuffaceous sandstone and siltstone deposited at STOP 2 by the 1982 mudflow on the lower Cowlitz River.

Figure 5. Lens of pebble-size rounded pumice clast in 1980 mudflow deposits at STOP 3.

57.7 STOP 3: Bridge over Toutle River. Stop to observe sedimentary features of the mudflows such as alluvial cut-and-fill, channel bars, point bars, small straight-crested and linguoid-lunate ripples, megaripples, cross-bedding, and pumice-clast lenses (Figure 5). Note transported stumps and logs. In this area, 1980 mudflow deposits were cut by flow from the 1982 eruption.

How high was the water level here on May 18, 1980? (Hint: Look at the trees and bridge pillars.)

Proceed south on the Old Pacific Highway.

2.0

59.7 Do you recognize the swamp on the right? (If not, review the road log).

0.5

60.2 Turn east (left) on Highway 504 towards Toutle, Washington. Optional stop to buy a St. Helens Frisbee. On this narrow road watch for logging trucks carrying St. Helens' harvest.

10.3

70.5 Enter outskirts of Toutle, Wash.

0.7

71.2 Turn right on South Toutle Road.

0.6

71.8 Mobile home rolled by mudflow.

0.3

72.1 House buried by mudflow. Should people whose homes were destroyed in this area be allowed to rebuild? This is a real question that the county and state are facing. Note transported jumble of stumps and logs mixed with trees killed and buried in situ. How could you tell the transported trees from the ones preserved in place after preservation in the fossil record?

0.2

72.3 STOP 4: Bridge over the South Fork of the Toutle River. Stop to observe the mixture of transported and in situ stumps and logs. How does the grain

Figure 6. Mixture of transported and in situ stumps and logs buried at STOP 5 by the mudflow. Arrows point to the 1980 mudflow level.

Figure 7. Upright stump transported by the 1980 mudflow and deposited upright in the center of Highway 504 near STOP 5. (From Fritz, 1980.)

size of the mudflows compare with that observed at STOP 2? Compare the sedimentation here with that along the North Fork of the Toutle. It appears that the 1982 mudflows did not affect this area. Turn around and head back west on South Toutle Road.

0.9

73.2 Turn right on Highway 504.

0.2

73.4 STOP 5: Pull off on old road to observe bridge washed out by mudflow and mixtures of transported and in-place logs and stumps buried by the mudflows (Figure 6). For those who still doubt that stumps can be transported and deposited upright, please observe upright stump (Figure 7) in the center of the old road (see Fritz, 1980). Note coarser grain size of sediments as compared to STOP 1. Continue north on 504.

0.6

74.0 Bridge over the Toutle River—CAUTION—this is a temporary one-way bridge. Note large boulders and numerous upright transported stumps. While continuing east along north bank of river, watch for mudflow deposits. Plans call for rebuilding the old bridge. When this occurs, you will need to adjust mileage beyond the point to account for abandonment of the loop across the temporary bridge. There is a place to pull off and stop to observe features just across the temporary bridge.

1.6

75.6 STOP 6: Good view of stream-reworked mudflows and buried upright stumps (Figure 8). Stop at viewpoint parking lot. Notice that the mudflows are much coarser grained here than they are downstream. Here they consist of gravel, cobble, boulder, and coarse sand conglomerate (Figure 9).

2.2

77.8 Keep right on Highway 504 at intersection with Highway 505.

1.7

79.5 Good viewpoint of transported stumps. Would you have wanted to be standing in the road here on May 18 to watch the eruption and the spectacular mudflows? See cliffs on the left for indications of mudflow levels. There are many pullouts and viewpoints from here on for optional stops to observe mudflow deposition along the North Fork of the Toutle River.

1.0

80.5 This is not, repeat **not**, part of the blowdown zone —it represents activity by *Homo sapiens.*

2.5

83 STOP 7: You have arrived at the boundary of the Blue Zone (previously the Red Zone boundary). Part of Highway 504 is washed out and im-

Figure 8. Upright-transported stump buried in alluvial deposits of reworked mudflow material at STOP 6. Note layering, coarse cobble grain size, and sedimentary features in the exposure.

passable 600 ft beyond the barricade. By walking down to the washed-out portion, you can observe the depositional sequence resulting from the 1982 mudflows. Head back west on Highway 504.

0.4

83.4 STOP 8: Turn right into viewpoint parking. Several houses and cars partially buried by the 1980 mudflow are still preserved here.

This is the end of the first portion of the road log. Return to Portland via Highway 504 to Interstate 5. For those persons with the proper entry permits and off-road vehicles, a second portion of the road log starts at the viewpoint at STOP 8 and continues to the new Red Zone (as of March 1982) at the earth dam above Camp Baker. This portion of the trip shows much coarser grained deposition and thicker sequences of both the 1980 and 1982 mudflow. Please note that all roads in the second portion are dirt logging roads with a high volume of heavy-equipment traffic. Many of the bridges and sections of the road are subject to washout. IT IS IMPERATIVE THAT YOU CHECK WITH THE AUTHORITIES FOR PERMITS AND A REPORT ON THE STATUS OF THE VOLCANO AND ROAD CONDITIONS BEFORE PROCEEDING.

Figure 9. Graded bed of conglomerate produced by the 1982 mudflow upstream from STOP 6. Shovel is 32 in. long.

00.0 Leave viewpoint parking lot. Turn west (right) on Highway 504.

1.1

1.1 Turn north (left) on dirt road No. 1900. First left past Kidd Valley Store.

0.5

1.6 Stay left on road No. 1900 at junction with road No. 1913.

0.3

1.9 Stay right on road No. 1900 at junction with road No. 1914 to the left.

1.7

3.6 Stay left (uphill) at intersection.

0.4

4.0 Take a hard left at maze of intersections. Stay on the well-traveled road No. 1900.

0.4

4.4 Stay right on No. 1900 at junction with No. 2410-J.

0.4

4.8 Continue straight on No. 1900 at junction with No. 2410-I.

0.6

5.4 Continue straight at intersection.

2.0

7.4 Continue straight on road No. 1900 at maze of intersections of roads No. 2410 and No. 2411. Be sure to check the warning light for possible flood hazard conditions before proceeding down to the stream bottom.

0.6

8.0 Arrive at edge of the North Fork of the Toutle River. Watch for features on the point bars from here on.

0.5

8.5 Turn left over Alder Creek.

0.2

8.7 Good place to stop and view mudflow and associated alluvial deposits.

0.3

9.0 STOP 9: Bridge over the North Fork of the Toutle River. Road now continues on the north bank. There is a good place to stop just across the bridge. From here walk downstream on the point bar to observe stream-reworked volcaniclastic material (Figure 10).

Figure 10. Graded bed of cobble pumice clasts fining upward to coarse sand deposited by the 1982 mudflow near STOP 9.

Figure 11. A braided portion of the North Fork of the Toutle River upstream from the debris dam at STOP 11. Braiding was caused by the high sediment load from the 1982 mudflow debris exposed in the cutbanks. Note the upright-transported stump on the channel bar in the lower right corner of the photo.

0.1

9.1 STOP 10: Stay right at junction with road No. 2500. Just past this intersection is a good place to stop and walk through the aspen grove on the right and down onto a large point bar. All of the trees in this grove were buried 0.5-1 m deep and killed by the 1980 mudflow. Note the new plants and the 1- to 5-cm-thick accumulation of organic debris on the surface. This is the start of the formation of a new soil.

0.7

9.8 Continue straight at intersections.

1.4

11.2 Center of Camp Baker. Excellent view of Mount St. Helens straight up the valley if the weather is clear.

1.4

12.6 Standing trees in the flats are on the very edge of the seared zone of the May 18, 1980, eruption (U.S. Geological Survey, 1980).

0.9

13.5 STOP 11: Boundary of the Red Zone at top of earthen flood control dam. Approximately 3-4 m of sedimentation occurred behind this dam the night of March 19, 1982 (Figure 11). The surface now preserves a good representation of the appearance of the flow. Note the large numbers of horizontal logs and vertical stumps on the surface. Counts taken two weeks after the 1982 eruption showed that 10.2 percent of the transported logs were transported and deposited upright. The horizontal logs were strongly oriented in a downstream direction by the flow. A walk across this surface shows excellent exposures of sedimentary structures. Walk downstream below the dam to observe the depositional sequence in both the 1980 and 1982 flows.

CONCLUSION

In this road log we have attempted to show the readily observable pattern of sedimentation resulting from the May 1980 and March 1982 eruptions of Mount St. Helens. Sedimentary features of these mudflows are extremely useful in understanding older volcaniclastic sediments. Mount St. Helens will likely continue producing mudflows in the near future. These mudflows will alter some of the specific details pointed out in this road log. However, the general patterns of sedimentation and points from which to observe them should remain unchanged.

ACKNOWLEDGMENTS

For the help in the field and for assistance in obtaining Red Zone permits, we thank Anthony Qamar, University of Montana and University of Washington. This work was partially supported by the Dean's Research Fund of the College of Arts and Sciences at Georgia State University. Ernest Fritz kindly provided field vehicles and assistance in the field. We also thank Tom Pierson, U.S. Geological Survey, David A. Johnston Cascades Volcano Observatory, Vancouver, Washington, for reviewing the manuscript.

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Guidebook on requirements for natural resource development

The U.S. Geological Survey has published guidebooks listing state requirements for development of natural resources in 40 states, including Oregon and all other western states.

The guidebooks provide information on how to obtain permits for activities such as drilling wells, mining, or collecting fossils and list and explain briefly the state regulatory requirements governing the development of energy and other natural resources. In addition to regulatory requirements, they outline procedures for permits, leases, and other documents; give estimates of the time and fees needed in obtaining the documents; and list the appropriate state agencies.

The guidebook on Oregon is available at no charge but in limited numbers from the Office of the Governor, State Capitol Building, Salem, OR 97310, attention Pat Amedeo, Room 160, phone (503) 378-3109. After the supply of free copies is gone, the guidebooks may be purchased from the Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225. Prices are \$3.50 for the microfiche version and \$13.50 for the paper copy. □

OIL AND GAS NEWS

Columbia County

Reichhold Energy Corporation's Columbia County 43-5, previously reported in July, was suspended June 17 at a total depth of 3,099 ft. The operator plans to re-enter it for redrill in approximately six months. The rig will next move to Columbia County 4, located in sec. 15, T. 6 N., R. 5 W., for redrill. This well, originally completed as a producer, flowed at the rate of 865 Mcfd in May 1979 but was never produced. Subsequent mechanical problems necessitate the redrill.

Clatsop County

Oregon Natural Gas Development Patton 32-9, located in sec. 9, T. 7 N., R. 8 W., 3 mi east of Olney, is drilling below 7,900 ft. Proposed total depth has been increased from 8,000 to 9,000 ft. Oregon Natural Gas currently has two additional locations in Clatsop County, each with a proposed total depth of 8,000 ft.

Douglas County

Florida Exploration Company 1-4, located near the town of Drain, is drilling ahead. Florida Exploration has three additional locations in Douglas County, each with a proposed total depth of 10,000 ft.

Hearings before the Governing Board

On June 29, a public hearing was held at St. Helens, Oregon, to consider rule changes governing oil and gas drilling and operation, specifically compulsory integration. The proposed changes include the addition of provisions to compensate the operator for financial risks incurred in the event of a discovery when there are unleased parcels in the spacing unit at the time of drilling. The proposed rule changes are currently being studied and will be acted on at the next Governing Board meeting.

Following this hearing, another public hearing was held to amend the interim order of September 29, 1981, integrating and pooling interests in the NE¼ sec. 15, T. 6 N., R. 5 W., Columbia County, Oregon. Reichhold Energy Corporation, the petitioner, proposed that the Board allow them to redrill their Columbia County 4 and to retain certain sums of money from escrow. The amendment to the Interim Order was approved and signed by the Board July 8, 1982.

Recent permits

Permit no.	Operator, well, API	Location	Status
218	Reichhold Energy Corp. Columbia County 32-9 36-009-00104	NE¼ sec. 9 T. 6 N., R. 5 W. Columbia County	Location

□

Washington geologists die in plane crash

E. Bates McKee, Jr., Affiliate Professor, and Randall L. Gresens, Associate Professor, both of the Department of Geological Sciences, University of Washington, Seattle, were killed in a light plane crash July 17, 1982, in the Wenatchee Mountains southeast of Wenatchee, Washington. Gresens' wife Mimi was also killed in the crash. McKee, who wrote the book *Cascadia: The Geologic Evolution of the Pacific Northwest*, was owner and pilot of the plane. □

BOOK REVIEW

by Ralph S. Mason, former State Geologist

The Geologic Story of the National Parks and Monuments, *third edition, by David V. Harris. John Wiley & Sons, 1980, 322 p., paperback $21.95.*

Good looks alone do not a good book make. Here is a book which, while concerned with some of the most beautiful scenery in the United States, makes a deliberate point of taking the reader behind the scenes to explain just how all of that wonderful real estate came to be that way. Probably more than 90 percent of all scenery is due to purely geologic processes and formations, and it is this 90 percent that the author takes under his wing.

Author David V. Harris taught for 30 years at Colorado State University, where he developed the geology program and offered one of the first courses in the geology of the national parks in the United States. Before embarking on a park-by-park description, he presents a mini-course in physical and historical geology in a long opening chapter. There is no excuse for not grasping the fundamentals of this body of science after one has read that chapter.

The main body of the book discusses 21 geomorphic provinces with "39 Parks, 30 of the most geologic Monuments, a National Lakeshore, a Seashore, and a National Parkway." Oregon is represented with the Oregon Caves National Monument in the Pacific Border Province and with Crater Lake National Park in the Cascades Province.

Since any discussion of geological phenomena must inevitably include a few special terms, the author has thoughtfully listed them in the glossary-index. A bibliography of selected geologic references contains nearly 400 entries.

The book seems to have at least one illustration per page, often more, approximately one-fourth in color. The cross section through the Grand Canyon has to be one of the finest around and greatly simplifies the vast complexities of the panorama that confronts the visitor. The text is well suited for the average tourist who is curious about the natural forces that created the geologic wonders framed in the view finder of his or her camera. For the armchair tourist, the volume offers enjoyable reading and the best possible alternative to actually being there. For the professional geologist, the book is a handy reference tool in responding to queries from the lay public. It is available from most bookstores, and a copy is available for inspection in the library of the Portland office of the Oregon Department of Geology and Mineral Industries. □

Northern Oregon Cascades geologic map released by PSU

The Earth Sciences Department of Portland State University announces the completion of a new map, *Preliminary Geologic Map and Cross Sections of the Upper Clackamas and North Santiam Rivers Area, Northern Oregon Cascade Range*, by Paul E. Hammond, Kathleen Manning Geyer, and James L. Anderson. The black-and-white ozalid map covers all or parts of six 15-minute quadrangles, including the areas around Austin, Bagby, and Breitenbush Hot Springs. Produced at a scale of 1:62,500, the map shows the areal extent of numerous geologic units, including surficial deposits, intrusions, and 20 volcanic units, ranging in age from about 25 m.y. to Recent. It is printed on a single sheet 67 by 42 in.

Cost of the map is $8 (folded) or $9 (rolled, in tube). Maps may be ordered prepaid from the Department of Earth Sciences, Portland State University, P.O. Box 751, Portland, OR 97207. □

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COVER PHOTO

Large landslide in marine terrace south of Yaquina Bay, Lincoln County, Oregon. The article beginning on the next page discusses landslides along the Lincoln County coastline. This photo was taken by Herbert G. Schlicker, consulting geologist, and originally appeared in the Department's Bulletin 81, *Environmental Geology of Lincoln County, Oregon*, which was published in the early 1970's.

Grand Ronde quadrangle map added to northern Coast Range studies

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released a new geologic map of the Grand Ronde 7½-minute quadrangle in northwest Oregon.

The multicolored map (scale 1:24,000) by former DOGAMI staff member Michael E. Brownfield covers an area mostly east of Grand Ronde and straddling the border between Polk and Yamhill Counties. It adds to the ongoing study of the northern Coast Range for oil and gas resource potential.

Seven surficial and bedrock geologic units are shown for the study area, as well as the geologic structure and several fossil localities. The map also includes a geologic cross section, tabulated information on fossils, and a discussion of stratigraphy, structure, and economic geology of the quadrangle.

The study produced significant stratigraphic and paleontological data for resource potential, although no exploratory holes have been drilled and no oil and gas has been found so far. Evidence was found showing that the contact between the Tyee Formation turbidites and the pelagic sediments of the Yamhill Formation is conformable and that the units are interbedded. Several major faults which were mapped may be related to late Eocene-Oligocene rotation of the Coast Range. The Yamhill Formation contains abundant organic matter and is considered a potential source rock for oil and gas.

Geologic Map of the Grand Ronde Quadrangle, Polk and Yamhill Counties, Oregon, is issued as Map GMS-24 in DOGAMI's Geological Map Series and is available now at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $5. Orders under $50 require prepayment. □

BLM compiles list of Oregon paleontological sites

The U.S. Bureau of Land Management (BLM) has compiled a catalog of paleontological sites on or near BLM lands in Oregon. Durga Rimal, geologist with the BLM's Oregon State Office, and Janet Schaller, recent geology graduate of the University of Oregon, have prepared a comprehensive list of localities, species, and literature citations for each of the BLM administrative districts. The 1981 catalog is available for reference in the BLM Oregon State Office in Portland and in BLM district offices throughout the state. A copy is also available for reference in the library of the Portland office of the Oregon Department of Geology and Mineral Industries. □

CONTENTS

The relationship of morphology and material to landslide occurrence along the coastline in Lincoln County, Oregon

by John R. Gentile, Department of Geography, Oregon State University, Corvallis, Oregon 97331

ABSTRACT

The exact locations of 153 landslides were delineated within a 2.1-km-wide strip along the Lincoln County, Oregon, coastline. Most of the landslides occur in conjunction with siltstone units of Tertiary age. Areas with similar morphology but of sandstone are less likely to have landslides. Structurally, landslides occur in areas with steeply dipping Tertiary bedding planes or in areas with steep slopes such as river valleys. A large portion of the landslides in the study area occurs at contact zones between Tertiary and Quaternary materials.

INTRODUCTION

Landslides are frequently occurring geologic hazards in Lincoln County, western Oregon. In the past, they have caused extensive damage to homes and property, particularly in the coastal zone. For that reason, the locations and frequency of landslides in a 2.1-km-wide strip of the Lincoln County coastline were compared with local rock types and geologic structure in order to identify the types of earth material and morphology most conducive to landslide activity. This type of knowledge can be used to reduce the occurrence and impact of these mass failures.

METHODOLOGY

Landslides along the Lincoln County coast were delineated by stereoscopic interpretation of aerial photographs and subsequent field verification. The landslides were identified by characteristic landslide features.

Recent landslides were quite easy to identify on aerial photographs. Characteristics included displaced buildings, recently repaired or disrupted stretches of highway, debris remaining on roadsides or beaches, leaning or fallen trees, distinct arcuate scars, the absence of vegetation on scarps, and sag ponds. Older landslides were somewhat more difficult to detect on aerial photographs but with practice could be recognized by remaining arcuate patterns and the hummocky surface of debris areas. In this study, any suspect areas were plotted on maps and subsequently verified in the field. Field evidence used to verify slides included cracked foundations on buildings, tension cracks on surface areas, scarps, leaning trees, seeplines, sag ponds, diverted drainage, displaced strata, debris accumulations, arcuate features, and hummocky surface areas. Other identifiable characteristics of landslides are described by Sharpe (1938) and Eckel (1958).

Table 1. *Description of geologic units along the Lincoln County, Oregon, coastal zone**

Geologic unit	Description and areal extent
Unit 1	Characterized by high cliffs (122 m) of Nestucca siltstones, protected from wave attack by resistant igneous dikes. (4.8 km^2)
Unit 2	Composed of Quaternary marine terrace deposits overlying seaward-dipping Tertiary siltstones of the Yamhill and Nestucca Formations. (30.9 km^2)
Unit 3	Composed of Quaternary marine terrace deposits overlying seaward-dipping Tertiary sandstones of the Yaquina Formation. (11.1 km^2)
Unit 4	Primarily Cape Foulweather and Depoe Bay Basalts protecting Tertiary sandstones and pockets of marine terrace deposits. (22.3 km^2)
Unit 5	Quaternary marine terrace deposits underlain by seaward-dipping Nye Mudstone, a siltstone of early Miocene age. (30.2 km^2)
Unit 6	Nearly horizontal deposits of marine terrace sediments overlying sandstones and siltstones. (68.3 km^2)
Unit 7	Highly weathered basalt regolith of late Eocene age, Yachats Formation. (12.8 km^2)

* Units are shown as reaches on strip maps on page 100.

Active rotational slump (Reach 5, Map 13, Landslide 7 on strip map) at the end of Agate St., Agate Beach north of Newport.

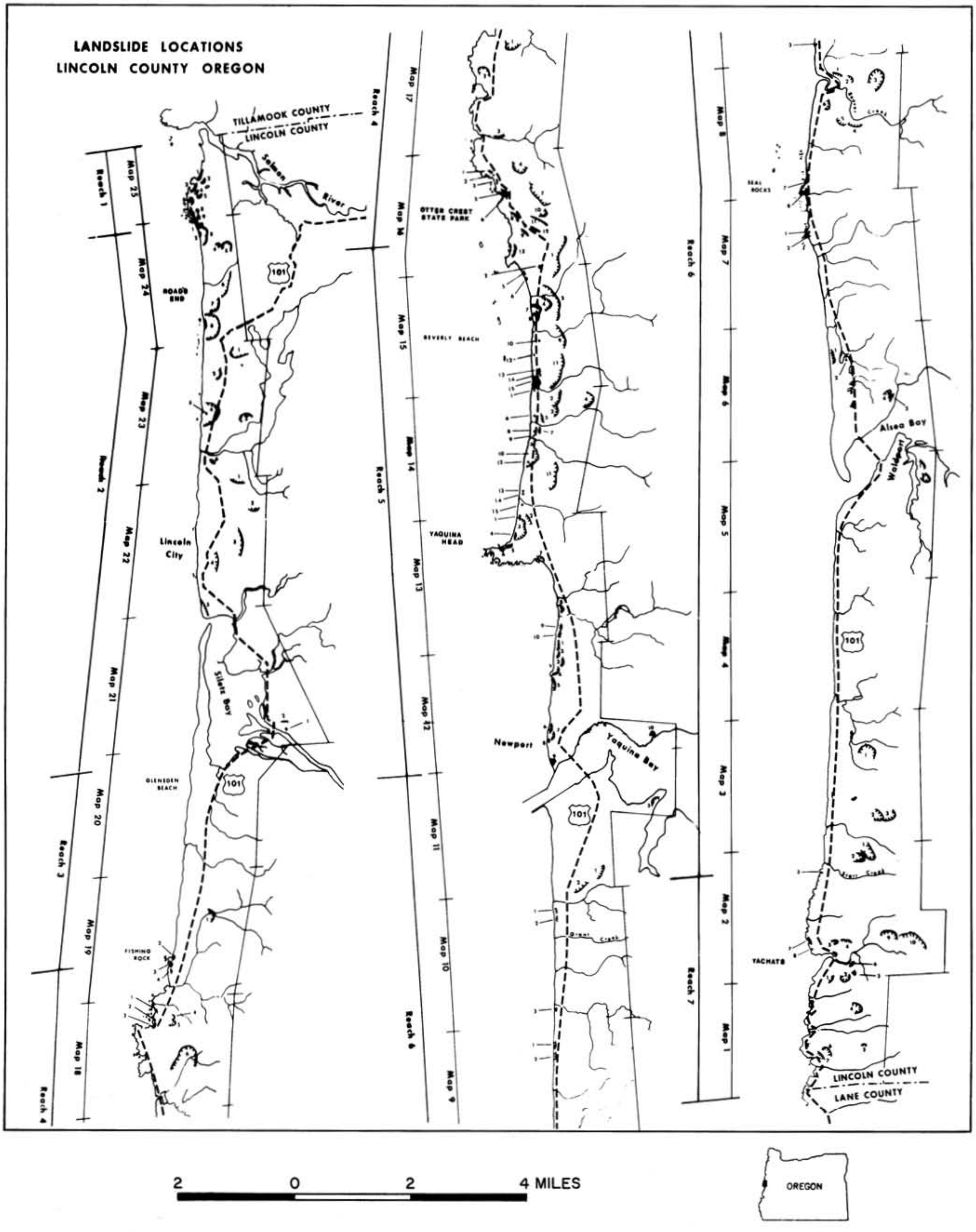
When a landslide was verified, its exact location was plotted on contact photo mosaics and topographic maps. The mosaics (scale 1:4,800) are on file at the Lincoln County Planning Department in Newport and correspond to the strip of the Lincoln County coastline designated as the study area.

From the characteristics exhibited by the landslides, it was possible to determine whether each slide was stable (showing no signs of movement), potential (likely to become active in the near future), or currently active. In addition, the sizes, aspects, and types of earth materials involved in the slides were determined.

It was suspected that the frequency and location of landslides would be related to the differing types of lithology and structure along the coastline. Therefore, the study area was divided into sections based on differing geologic materials and morphologies. Seven distinct reaches (or units) were identified from field observation and from existing geologic maps (Schlicker and others, 1973). The units are described in Table 1 and shown as reaches on the strip maps on page 100.

RESULTS AND DISCUSSION

This study indicates that the combined influences of lithology and structure determine the location and frequency of landslides in Lincoln County (Table 2). Considering the magnitude and number of landslides, Unit 5 is by far the most sen-


LANDSLIDE LOCATIONS
LINCOLN COUNTY OREGON
TILLAMOOK COUNTY
LINCOLN COUNTY
Salmon River
ROADS END
Lincoln City
Siletz Bay
GLENEDEN BEACH
FISHING ROCK
OTTER CREST STATE PARK
BEVERLY BEACH
YAQUINA HEAD
Newport
Yaquina Bay
SEAL ROCKS
Alsea Bay
Waldport
YACHATS
LINCOLN COUNTY
LANE COUNTY
101
Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
Reach 6
Reach 7
Map 25
Map 24
Map 23
Map 22
Map 21
Map 20
Map 19
Map 18
Map 17
Map 16
Map 15
Map 14
Map 13
Map 12
Map 11
Map 10
Map 9
Map 8
Map 7
Map 6
Map 5
Map 4
Map 3
Map 2
Map 1
2 0 2 4 MILES
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Active compound rotational slump (Reach 5, Map 12, Landslide 3 on strip map) on west side of Park Drive, in the vicinity of N. 14th St., Newport.

sitive to landslide activity, having a third of the slides in the entire study area. The largest active landslides also occur in this unit. In Unit 5, as in most of the study area, the materials involved in the slides are marine terrace deposits that overlie inclined siltstones. Siltstones, particularly the Nye Mudstone, seem most conducive to landslide activity.

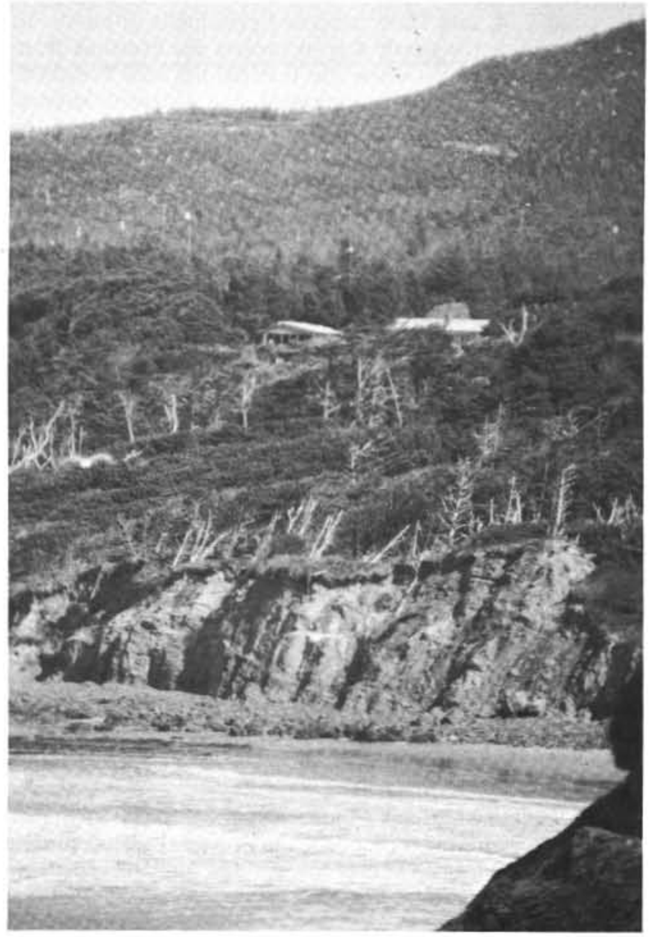
In areas where the marine terrace deposits overlie sandstones, landslides are less likely to occur, even if the dip of the Tertiary beds is similar. This becomes evident in a comparison of Units 2 and 3. Unit 2, which is underlain by siltstone, has numerous landslides, whereas Unit 3, which is similar to Unit 2 except for the sandstone lithology, has only one landslide, and it occurs in an outcrop of siltstone. In fact, only five landslides in the entire study area occur in sandstone. Interestingly, all of these are in conjunction with siltstone or basalt surface contact.

Unit 6, the unit with largest areal extent in the study area, is similar to Units 2 and 3 in lithology; however, the dip of the Tertiary materials is less than in the other units, as is the total relief. This difference in structure results in relatively fewer landslides in this area. Slides which do occur in Unit 6 are smaller by comparison, occurring in the marine terrace deposits along the coast or in river valleys where the slopes are steeper.

Most of the landslides in the study area occur either along the coast or at surface contact zones where two materials come together. Landslides occurring at the contact zones are usually larger than other slides in the study area. Ground-water seepage and the differing porosities of the materials may be a factor in these areas.

Active slump (Reach 5, Map 12, Landslide 5) on south side of Jumpoff Joe, N. 10th and Coast St., Newport.

← Facing page. Strip maps showing landslide locations along the coast in Lincoln County, Oregon. Reach numbers correspond to geologic units as they are described in Table 1; map numbers refer to photo mosaics kept in the Lincoln County Planning Department in Newport, Oregon; slide numbers identify each landslide on separate photo mosaics. A description of each slide, including location, size, type, and status, appears in the appendix of the author's thesis (Gentile, 1978).



Active rotational slump (Reach 5, Map 13, Landslides 3 and 4 on strip map) along coast at Agate Beach. Note angles of trees.

Table 2. *Landslide numbers by status and unit*

Unit	Status			
	Active	Potential	Stable	Total
1	7	1	3	11
2	1	7	13	21
3	0	0	1	1
4	1	11	12	24
5	26	12	13	51
6	10	1	20	31
7	0	5	9	14
Total	45	37	71	153

Units 1, 4, and 7 are composed principally of basalt. In Units 1 and 4, the basalt acts to protect the coastline from wave attack. In places where this material has been breached, however, wave energy is concentrated, and damage is intense. As evidence, notice the number of coastal slides in Unit 1. In Unit 7, the basalt material is seldom breached at the coast. Most of the slides in this area occur farther inland and are involved in deeply weathered basalt regolith. Landslides in Unit 7 are considered the most devastating when they occur because they are usually triggered in periods of high rainfall and take the form of rapid debris flows or torrents.

CONCLUSION

When frequency and location of landslides were compared with the differing geologic units, it was possible to determine which types of earth materials and morphologies were most conducive to landslide activity. In Lincoln County, it was found that areas composed of seaward-dipping Tertiary siltstones are by far the most sensitive to landslides, particularly at geologic contact zones.

It is likely that landslides will always be a hazard in Lincoln County. However, knowledge of where landslides have occurred in the past and what materials are most conducive to landslides makes it possible to anticipate where slides are most likely to occur in the future. This information will enable land use planners in Lincoln County as well as other coastal counties to implement programs which will lessen the impact of landslides in the future.

ACKNOWLEDGMENTS

I would like to thank Charles Rosenfeld for his assistance as my major advisor throughout the project. I would further like to acknowledge Thomas Maresh and Joe Dills for their suggestions on the final paper.

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Schuster leaves Department to enter law school

Stephen Schuster, Field Representative for the Mined Land Reclamation Program, has resigned his position to enter law school at the University of Oregon. He joined the Oregon Department of Geology and Mineral Industries (DOGAMI) in 1980 after overseeing coal mine reclamation with the Illinois Department of Natural Resources. While with DOGAMI, Schuster was responsible for insuring that all surface mines in the northern half of Oregon were in compliance with Mined Land Reclamation laws. □

Men argue, Nature acts. — *Voltaire (1694-1778)*

OIL AND GAS NEWS

Columbia County

Reichhold Energy Corporation's Columbia County 4, redrill, located in sec. 15, T. 6 N., R. 5 W., was completed as a gas well July 24, 1982. Flow rate was 2.24 MMcfd.

Reichhold Energy Corporation's Columbia County 32-33, located in sec. 33, T. 7 N., R. 5 W., was drilled to a total depth of 2,614 ft. The well was then plugged back and redrilled to a total depth of 3,030 ft. Present plans are to plug and abandon.

Clatsop County

Oregon Natural Gas Development Corporation's Patton 32-9, located in sec. 9, T. 7 N., R. 8 W., 3 mi east of Olney, is drilling below 9,600 ft. This well was re-permitted, and proposed total depth was increased to 10,000 ft. Oregon Natural Gas currently has two additional locations in Clatsop County, each with a proposed total depth of 8,000 ft.

Douglas County

Florida Exploration Company's Harris 1-4, located near the town of Drain, is testing. Florida Exploration has three additional locations in Douglas County, each with a proposed total depth of 10,000 ft.

Oil and gas rules adopted

A meeting of the Governing Board of the Oregon Department of Geology and Mineral Industries was held August 11 in Portland. New rules adopted provide for compulsory integration of ownership interests in a spacing unit when there are unleased parcels. The rules also provide for the drilling and operation of a well, sharing of production, and payment of costs. □

Revised oil and gas well records list available

The Oregon Department of Geology and Mineral Industries (DOGAMI) has published a revised list of its oil and gas well records for Oregon. DOGAMI Miscellaneous Paper 8, *Available Well Records of Oil and Gas Exploration in Oregon, Revised April 1982*, was compiled by W.L. King, D.L. Olmstead, and V.C. Newton, Jr., and supersedes the update of March 1980.

The paper lists all available well records of oil and gas exploration drilling in Oregon since 1909 in tabular form by county. For each well, the table indicates company and well name; location, date, and depth of the well; and nature and availability of lithologic descriptions, logs and surveys, and samples held in the DOGAMI collection. An orientation map of Oregon shows the Township and Range system to aid in locating the wells. The preface also lists addresses of firms that can provide copies of the complete well records.

Miscellaneous Paper 8 is available at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $4. Orders under $50 require prepayment. □

E.F. Lange dies

Erwin F. Lange, retired Professor of General Science and Assistant Dean of the College of Science at Portland State University, died Thursday, August 19, in a Milwaukee hospital. The author of a college science workbook and numerous articles on science, he was also a Northwest specialist on meteorites. He will be remembered by readers of *Oregon Geology* for his work with Hollis Dole and Phil Brogan on the Year of the Meteorite in 1968. □

Our ever-changing world

by Raymond E. Corcoran, Consulting Geologist, Portland, Oregon

This article originally appeared in *The Geological Newsletter* (March 1981, v. 47, no. 3, p. 32-34) of the Geological Society of the Oregon Country. We are reprinting a revised version of it here because we believe that it may be of interest to our readers. The author, R.E. "Andy" Corcoran, was with the Oregon Department of Geology and Mineral Industries from 1953-1977, except for 1957-1960, when he was Chief Geologist for Harvey Aluminum Company. During his years with the Department, he authored numerous articles and publications and served as State Geologist from 1969-1977. He resigned this position to become Special Assistant for Environmental Assessment under the U.S. Bureau of Mines' Associate Director of Minerals and Materials Research and Development in Washington, D.C. He returned to Oregon in the fall of 1980, where he is now a consulting geologist.

The recent eruptions at Mount St. Helens north of Portland and major earthquakes and volcanic eruptions in other parts of the world have created considerable public concern about the effects of such activities on human beings and their habitations. Such geologic catastrophes are not uncommon, and the history of mankind is replete with stories of such disasters.

Probably the most famous volcanic eruption was that of Mount Vesuvius in A.D. 79, during which the Roman cities of Pompeii, Herculaneum, and Stabiae were overwhelmed by rivers of mud and showers of ash. In 1902, Mount Pelée on the island of Martinique was vigorously active over several months. On May 8 of that year, pyroclastic flows similar to those observed during some of the St. Helens eruptions roared down a valley at more than 60 mi per hour and engulfed the port of St. Pierre. Of the 28,000 inhabitants, only one man, imprisoned in an underground dungeon, survived the hot blast. Crime sometimes *does* pay!

The strongest known volcanic explosions have occurred in long-dormant composite volcanoes like those that make up the High Cascades in Oregon, Washington, and northern California. One of the greatest of such explosions happened in April 1815, when the Indonesian volcano, Tamboro, was decapitated. Thirty-six cu mi of molten lava and solid rock were shattered into fragments and blown high into the air, scattering pyroclastic debris over more than 100,000 sq mi. The mountain lost 4,200 ft in height and formed a crater 7 mi in diameter —greater in size than many calderas. A large number of people were killed, but no one was able to make a reasonable estimate at that time. With some exceptions, most volcanic eruptions have taken place in areas of relatively sparse population.

Not so as regards earthquakes. In the early morning of November 1, 1755, a temblor struck Lisbon, Portugal. The wild shaking apparently lasted for several minutes, and before it finally stopped, it created a 50-ft wave (tsunami) that crashed into the harbor and essentially completed the destruction of the city. There were at least two major aftershocks as well as numerous fires during the day; by nightfall, 60,000 people out of a population of 235,000 had perished.

In the United States, one of the first recorded earthquakes was that of New Madrid, Missouri, on the banks of the Mississippi. A huge tract of land nearly 150 mi long and 35 mi wide sank, in places as much as 10 ft, to form new lakes and swamps. The tremors stopped pendulum clocks and rang church bells as far away as Boston. Had this earthquake come a century later, the loss of life would have been tremendous.

In 1976, a major earth shock in northern China caused widespread destruction and killed an estimated 250,000 people. On October 10, 1980, the city of El Asnam in Algeria was essentially destroyed by a series of at least 20 temblors, the initial registering 7.5 on the Richter scale. Early estimates indicated that at least 3,500 people were killed, about 8,000 were injured, and about 4,000 were left homeless. Many other horror stories of the damage caused by such catastrophes could be recounted that clearly document the fact that the earth is a dynamic system, not a static one.

Are the vast changes that have taken place on the surface of the earth over the last few billion years the result of many such sudden terrifying geologic events? Most earth scientists today would argue that geologic "catastrophes" have not played a major role in shaping the earth's surface, but it wasn't too many years ago when they would have been very much in the minority. In the days before geology and geologic concepts were established as a science, people assumed that destructive events that came with such little warning were "Acts of God" as punishment for sins or other transgressions. During the early eighteenth century a doctrine called "Catastrophism" was widely prevalent. Very simply stated, the belief of the catastrophists was that all major changes came about as a result of successive destructions of the surface of the earth by violent and supernatural cataclysms, of which Noah's Flood was the classic example. Even today there are people who are convinced that "the end is near," and they cite what appears to them to be an ever-increasing tempo of "fire and destruction" that presages the final holocaust. It is easy to see how the "catastrophic doctrine" can have wide popular appeal when there is so much evidence of change caused by earthquakes, volcanoes, landslides and floods. It should also be remembered that less than 200 years ago the world was thought to have been created in 4004 B.C., which would have meant that changes in the earth had to move fairly rapidly if tall mountains and deep valleys were to be formed in that rather brief time span.

One of the modern triumphs of geology and physics, however, is the demonstration that the age of the earth cannot be less than 4.5 billion years. James Hutton (1726-1797), known as the Founder of Modern Geology, was the first scientist who clearly understood the significance of geologic time in explaining the development of the earth's surface. Sir Charles Lyell (1797-1875) used the term "uniformitarianism" to describe the concept that the laws of nature as we see them operating today furnish the best clues about how things happened in the past. Although most geologic processes such as uplift, erosion, and sedimentation operate slowly, their cumulative effects can be significant.

In his presidential address to the Geological Society of America, James Gilluly gave some interesting data to support the principle of uniformitarianism. At the Buena Vista field in the San Joaquin Valley of central California, a thrust fault had advertised itself by cutting off several oil-well casings. There had been no perceptible earthquakes in this area, but since it had been first noticed, the thrust block had moved about 1 in. per year, a rate of uplift of about 4 ft per century. At this rate, in a mere 25,000 years, the Buena Vista field would be 1,000 ft higher on the upthrown side, if there were no appreciable erosion. If this rate were to continue for 200,000 years (still a small segment of time in the geologic sense), the Buena Vista Hills would be as high as the Cascades of Oregon. Gilluly cited another example located south of San Francisco near the town of Hollister, where one segment of another, much better known fault, the San Andreas fault, is moving an inch or two a year and slowly tearing a winery apart, although the area remains seismically quiet. This type of tectonic activity is known to be occurring in various other parts of the globe as well but can be detected only through precise measurements.

It is true, of course, that volcanism is usually a constructive process, but in many instances, the effects of such events are geologically ephemeral. I can cite two examples in Oregon. Hole-in-the-Ground, a crater near Bend almost 1 mi wide and 400 ft deep, is the result of a tremendous steam explosion produced when hot magma ascending through the crust came into contact with water-impregnated sediments. Although the blast hole produced by the explosion is spectacular, it is already beginning to fill in, and tourists visiting the site 25,000 years from now will hardly be impressed. In east-central Oregon near Burns, a pyroclastic eruption between 14 and 15 million years ago poured out a blanket of volcanic ash that covered at least 12,000 sq mi to depths of as much as 150 ft. Although this event was truly a major geologic catastrophe affecting an extremely large area, its effect on the underlying topography was minimal. Subsequent stream erosion has carried away most of this welded ash flow, and there are now only scattered remnants to show its former broad extent.

What we can conclude from these examples is that the normal processes of geologic uplift, erosion, and subsequent deposition are going on continuously but quietly in all of the continental areas. As would be expected, there are doubtless variations in the rates with which these different processes take place, but the changes induced are difficult to discern during the normal course of a human lifetime. It is only when an area is viewed on the geologic time scale that the magnitude of the change can be appreciated. Geologic catastrophes will continue to occur, and in the specific areas affected, there will often be serious loss of life and extensive property damage. There will even be some modification, in one way or another, of the local topography. But when the broader region in which these events take place is included, it can be seen that the local disruptions become almost insignificant. Perhaps we can draw some comfort from the generally prevailing view that the rate of intensity of sudden geologic events does not appear to be increasing. Barring the accidental collision with a comet or another planet, the earth and its inhabitants are likely to be around for quite a few years. The uniformitarianism of Lyell seems not yet to require any amendments. □

GSOC luncheon meetings announced

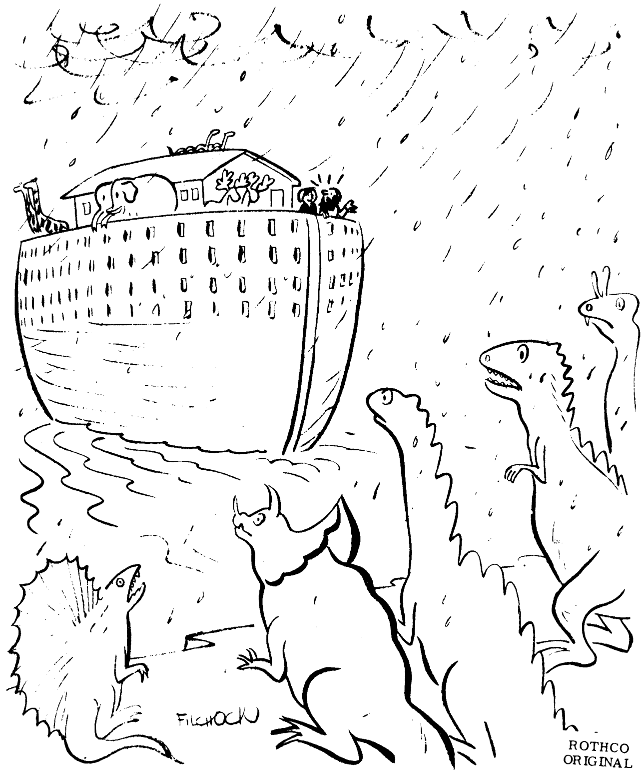
The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

September 17—*Pacific Coast Trail: Canada to Mexico (Part I, Oregon and Washington)*: by Eric Terhaar, outdoorsman.

October 1—*Pacific Coast Trail: Canada to Mexico (Part II, California)*: by Eric Terhaar, outdoorsman.

October 15—*Florida Everglades and Keys*: by Clair Stahl, GSOC President, 1974.

For additional information, contact Viola L. Oberson, Luncheon Program Chairwoman, phone (503) 282-3685. □



"BUT, DEAR, I CAN'T HELP IT IF WE'RE FULL UP - I'LL BE BACK FOR THEM LATER!"

AIME to hold first fall meeting

The Oregon section of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) will hold its first meeting of the fall on Friday, September 17, at the Copper Kitchen at the Wilsonville exit of I-5. Beverly Vogt will give a talk on the geology of the Bull Run Watershed.

A social hour will begin at 6 p.m., followed by dinner at 7 p.m. and talk at 8 p.m. For reservations, contact Mike York in Corvallis, phone (503) 757-0349, or the Portland office of the Oregon Department of Geology and Mineral Industries, phone (503) 229-5580. The public is invited. □

Geothermal meeting set for October

The Geothermal Resources Council will hold its annual meeting October 11-14, at the Sheraton Harbor Island Hotel, San Diego, California. Scheduled are technical sessions on power generation; reservoir technology; regulatory/environmental; exploration geology, geochemistry, and geophysics; direct use; and drilling/stimulation as well as poster sessions on geology, geochemistry, geophysics, drilling/stimulation technology, direct use, power generation, regulatory/environmental, and reservoir technology. Field trips to the Imperial Valley, Cerro Prieto, and north end of the Salton Sea are also planned.

For information concerning reservations or arrangements, contact Beverly Hall, Geothermal Resources Council, phone (916) 758-2360, or write Geothermal Resources Council, 1982 Annual Meeting, P.O. Box 1350, Davis, CA 95617. □

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.

STRUCTURAL GEOLOGY OF THE SOUTHEAST QUARTER OF THE DUTCHMAN BUTTE QUADRANGLE, OREGON, by Gerald Lee Black (M.S., Portland State University, 1979)

Field work in the southeast quarter of the Dutchman Butte quadrangle, which lies within the Klamath Mountains geomorphic province of southwestern Oregon, was completed during the summers of 1973 and 1974. The objectives of the study were fourfold: (1) to produce a geologic map of the southeast quarter of the Dutchman Butte quadrangle, (2) to determine the nature of the contact between the Dothan and Rogue Formations, (3) to construct a stratigraphic column of the Dothan Formation in the area, and (4) to attempt to determine the nature of the deformation occurring in the area.

Nearly 90 percent of the study area is underlain by sedimentary rocks of the Dothan Formation. Approximately one-half of the formation is composed of graywacke, one-third is composed of shale, and the remainder is basalt, conglomerate, and chert. The rocks of the Dothan Formation have been tightly folded, resulting in a general northeast strike and moderate to steep dips to the southeast. The Rogue Formation, which occupies the southeast corner of the study area, is in contact with the Dothan Formation along a northeast-trending reverse fault. The andesitic to basaltic volcanic rocks of the Rogue Formation have been intruded by granodiorite and serpentinite, which was emplaced along a second northeast-trending reverse fault. A small block of amphibolite, probably tectonically rafted to the surface along with the serpentinite, occupies the extreme southeast corner of the study area.

The Dothan Formation is divided into three members, which correspond in part to three of the four zones described by Wells and Walker (1953) in the Galice quadrangle to the immediate south of the study area. The uppermost member (member 4, corresponding to zone 4 of Wells and Walker) is composed of shale at the base followed by rhythmically bedded sandstone and siltstone. Present at the top of the member are 275 m of basalts. The middle member (member 3, corresponding to zone 3 of Wells and Walker) is composed primarily of massive, medium-grained sandstone units separated by thin shale partings. The lowermost member (member 2, corresponding to zone 2 of Wells and Walker) is composed of rhythmically interbedded sandstone and shale, with sandstone predominating slightly in abundance over shale.

The nature of the contact between the Dothan and Rogue Formations has been a subject of controversy until the early 1970's. Within the study area, highly sheared sandstones and shales of the Dothan Formation were found to pass abruptly into greenschist-facies rocks of the Rogue Formation. The transition is not gradational. At one point a large block of serpentinite was found emplaced in the contact zone, further substantiating the view that the Dothan and Rogue Formations are in contact along a northeast-trending reverse fault.

The dominant structural trend in the Dothan and Rogue Formations is northeast with moderate to steep dips to the southeast, the result of very tight isoclinal folding. The analysis of sixteen domains reveals the presence of an east-southeast fold axis trend superimposed on the stronger northeast trend. The northeast trend probably results from middle of the Cretaceous eastward underthrusting of oceanic crust, while the east-southeast trend probably results from early Tertiary deformation.

The Rogue Formation represents an island arc assemblage that was metamorphosed, uplifted, and deformed in the Late Jurassic Nevadan Orogeny, while the Dothan Formation represents a younger, post-Nevadan arc-trench gap sedimentary assemblage that was deposited primarily by turbidity currents and obducted onto the North American plate during the middle of Cretaceous time.

VOLCANISM AND STRUCTURE IN THE VICINITY OF ECHO MOUNTAIN, CENTRAL OREGON CASCADE RANGE, by Walter Avramenko (M.S., University of Oregon, 1981)

The region surrounding Echo Mountain in the central Oregon Cascade Range was examined in order to work out the sequence, timing, and petrological character of the volcanic events which took place during the transition from Western Cascade to High Cascade volcanism. The calc-alkaline rocks exposed in this area can be subdivided into three major groups on the basis of petrologic features and age. The early to late Miocene Western Cascade Series consists primarily of a thick sequence of silicic pyroclastic rocks that are overlain by andesite lava flows. Following a period of deformation and erosion, these volcanic products were unconformably overlain by a number of coalescing basaltic shield volcanoes belonging to the late Miocene-early Pliocene Intermediate Series. These lavas were erupted within a relatively brief time interval from both pipelike vents and numerous northwest-trending fissures. Major- and trace-element abundances suggest that the Intermediate Series evolved from a water-undersaturated body of magma undergoing progressive fractional crystallization at about 2 kilobars. Late Pliocene to Holocene lavas were assigned to the High Cascade Series.

The rocks of this region are broken along N-S trending normal faults belonging to the western margin of the High Cascade graben, a few of which may have formed less than 1 m.y.a.

THE WESTERN CASCADE-HIGH CASCADE TRANSITION IN THE McKENZIE BRIDGE AREA, CENTRAL OREGON CASCADE RANGE, by Gerard Martin Flaherty (M.S., University of Oregon, 1981)

A geological study of the McKenzie Bridge area established the volcanic stratigraphy and structural relationships at the Western Cascade-High Cascade contact. Rocks of the thesis area were divided into four main groups, according to lithology and stratigraphic position. The mid- to late Miocene Western Cascade Series consists primarily of andesitic and dacitic flows. The Western Cascade Series is unconformably overlain by basaltic shield lavas of the Intermediate Series (7-5 m.y.). Normal faulting at the present-day Western Cascade-High Cascade contact occurred between 5 and 3 m.y. ago. Dip-slip displacement across the Horse Creek fault zone exceeds 2,000 ft (600 m). Following a considerable period of erosion, basalt flows covered the down-dropped eastern block and flowed into an ancestral McKenzie River valley. Shield lavas of the High Cascade platform unconformably overlie the Plio-Pleistocene basalts.

Chemical and petrographic differences between rocks of the Intermediate Series are explained with a simple petrologic model. Basalt flows erupted after the episode of normal faulting have primitive, mildly alkaline compositions. □

BOOK REVIEW

by Ralph S. Mason, former State Geologist

From time to time we print reviews of books that have been recently added to our library. These books are available for inspection only in the library, which is located in Room 901, State Office Building, Portland.

Asian Mining '81, by the Council of the Institution of Mining and Metallurgy, London, England. 311 p., 1981, paper $100.

Publications put together by a committee quite often remind one of the old saw about the design and construction of the giraffe. The committee that produced this publication, however, proves to be the exception, and it has been turning out similar technical publications for more than ten years.

As its title suggests, this work is about the many phases of mining and mineral extraction in Asia, from Japan in the north to New Guinea in the south, including Thailand, India, Burma, the Malay Peninsula, and the Philippines. Minerals discussed in the various papers include gold, tin, chromite, copper, lead, zinc, and coal. Mining is a truly international activity, and some of the titles of the papers have a familiar sound to Western readers. Papers dealing with electrical blasting hazards, taxes, exploration techniques, structural controls, radioisotope X-ray analysis, flotation and carbon-in-pulp extraction of gold would be welcomed by attendees at conferences meeting east of the Pacific.

One would think that tin, which has been mined in Thailand for several centuries, would hardly rate much attention at a meeting characterized by up-to-the-minute papers. Problems do keep coming up for tin, though, and one of the present concerns in Thailand is familiar elsewhere as well—land use planning. Farmland lying north of a long-established mining boundary is now being eyed for tin dredging. Mining is serious business in Thailand, where more than 30 minerals are extracted. Ownership of all minerals is vested in the Crown, and all mining is conducted by license or lease. Although government policy encourages mineral development by the private sector, the Department of Mineral Resources has the duty to promote and sometimes initiate mining ventures.

Although the character and quality of the 31 papers included in the publication vary somewhat, the level is generally high, the illustrations are exceptionally clean and clear, and the reproduction and format good. Apparently each author was responsible for not only writing and illustrating his own paper but also preparing it camera-ready as well. The committee enforced rather rigid specifications, since the publication as a whole avoids that patchwork appearance characteristic of similarly prepared publications. □

National Speleological Society produces guidebook for central Oregon lava tubes and other volcanic features

The National Speleological Society held its annual convention June 27 through July 3 in Bend, Oregon. Copies of guidebooks produced for the convention may be obtained from Ellen M. Benedict, 8106 SE Carlton St., Portland, OR 97206, phone (503) 774-1233. The 47-page book, entitled *Caves and Other Volcanic Landforms of Central Oregon*, costs $3, plus 50¢ for postage. □

Mineral exploration expenditures in Oregon in 1981

Mineral exploration expenditures continued to increase in Oregon in 1981. Private companies expended $11.2 million last year compared to $5.62 million in 1980 in the search for new ore deposits which was concentrated in Baker and Grant Counties in the Blue Mountains of northeastern Oregon. The principal target of exploration organizations in 1981 was gold, with lesser emphasis on base metals. Chromite received renewed attention during the past year.

The greatest expenditure was made in the search for petroleum and natural gas. Approximately $31.2 million was spent in exploration for hydrocarbons.

Although geothermal energy exploration surged in 1981 compared to earlier years, the total effort was moderate.

The following table shows private sector expenditures for recent years:

Mineral exploration expenditures in Oregon

	Metals (millions of dollars)	Oil and gas (millions of dollars)	Geothermal (private) (millions of dollars)
1981	$11.20	$31.20	$5.11
1980	5.62	25.80	2.79
1979	4.04	10.70	1.93
1978	4.44	4.60	1.30
1977	3.60	2.00	0.60
1976	2.30	2.00	1.40 □

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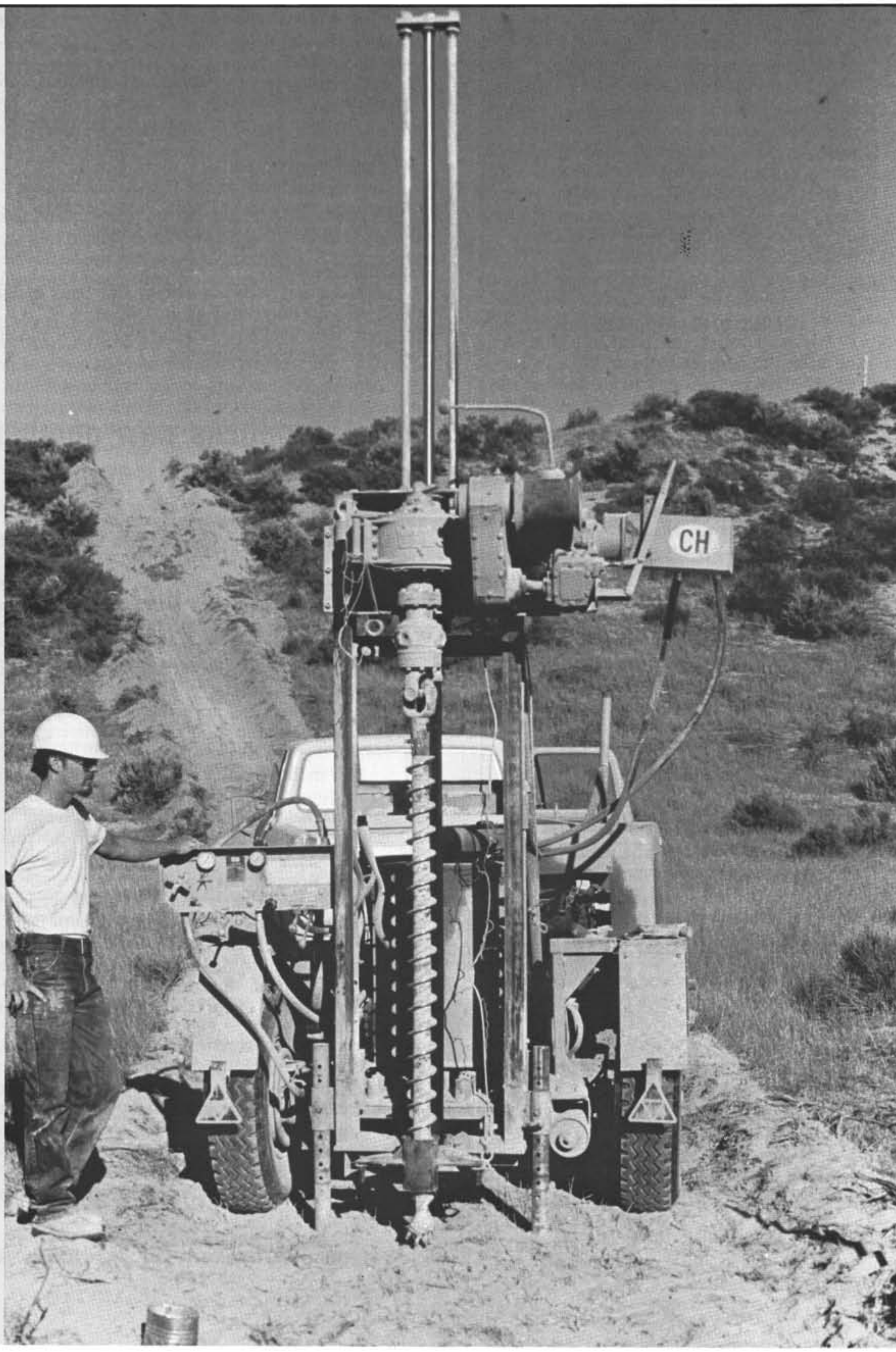

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COVER PHOTO

Diesel-powered auger drill rig used in assessment work on Oil-Dri's diatomite claims and property in the Fort Rock basin near Christmas Valley, Lake County, Oregon. Article beginning on next page discusses the stratigraphy of this area.

OIL AND GAS NEWS

Columbia County

There has been no drilling at the Mist Gas Field since last year. However, Reichhold Energy Corporation, operator of all nine producing wells at Mist, plans to drill Adams 34-28 in sec. 28, T. 7 N., R. 5 W. The well will be just north of the field boundary and 1 mi from the producer Longview Fibre 12-33. The proposed depth is 3,000 ft, to intersect the already productive Clark and Wilson sand of the Cowlitz Formation.

Clatsop County

Work continues on Oregon Natural Gas Development Corporation's Patton 32-9 to sidetrack junk in the hole. A sand, penetrated by the original hole, will be tested.

Douglas County

Testing continues on the Florida Exploration Company's 1-4 well near the town of Drain. Three permitted locations remain for the company in Douglas County.

Yamhill County

Nahama and Weagant Energy Company of Bakersfield, California, will soon spud Klohs 1 in sec. 6, T. 3 S., R. 2 W. The well, permitted to 6,000 ft, will test the anticline underlying the Chehalem Mountains. □

NOAA produces new geothermal resource map of Oregon

A new, comprehensive map of the geothermal resources of Oregon is available now through the Oregon Department of Geology and Mineral Industries (DOGAMI).

The multicolor map (scale 1:500,000) was produced by the National Oceanic and Atmospheric Administration (NOAA) for the U.S. Department of Energy and is based on data compiled by DOGAMI. On a sheet about 4 by 5 ft in size, it presents a summary of the current knowledge about geothermal resources in the state.

The map shows all known thermal springs and wells, identifies heat flow stations, and gives brief descriptions of major geothermal regions. Shading and coloring are used to indicate areas where thermal waters warm enough for direct utilization have been found or are likely to be found at shallow depth. Similarly, those areas where wilderness, national park, or reservation status limits geothermal development are identified.

Printed alongside the map are a county-by-county tabulation of all thermal springs and wells and a separate city map and thermal well list for the City of Klamath Falls.

The new map, *Geothermal Resources of Oregon, 1982*, can be purchased for $3 from the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. Orders under $50 require prepayment. □

CONTENTS

The geology of economically significant lower Pliocene diatomites in the Fort Rock basin near Christmas Valley, Lake County, Oregon

by G. Kent Colbath and Matthew J. Steele, Department of Geology, University of Oregon, Eugene, Oregon 97403

INTRODUCTION

During the summer of 1981, we were employed by the Oil-Dri Corporation of America to undertake assessment work (under the direction of R.C. Valenta) on its diatomite claims near Christmas Valley, Lake County, Oregon (Figure 1). Oil-Dri specializes in the production of oil and grease absorbents and cat litter. Absorbent products are currently being produced from crushed diatomite at the Christmas Valley plant (Figures 2 and 3).

The assessment work involved detailed examination of surface exposures of diatomite, extensive shallow drilling, and measurement of important physical properties. The material was examined microscopically for evaluation of its potential use in filtration products.

The direct economic implications of this assessment constitute proprietary information and will not be discussed here. In this paper, instead, we present observations that are primarily of academic geological interest. We wish to emphasize, however, that a better understanding of the geology of these diatomite deposits should ultimately aid in the evaluation of their economic utility, both in the Fort Rock basin and elsewhere in eastern and central Oregon.

PREVIOUS WORK

Our area of study is located in the Fort Rock drainage basin, which, according to Baldwin (1976), marks the boundary between the High Lava Plains physiographic province to the north and the Basin and Range province to the south, although Lawrence (1976) places the boundary between these two provinces north of the basin along the Brothers fault zone. Donath (1962) mapped faults along the southern margin of the basin and ascribed their origin to Basin and Range style deformation.

Moore (1937) published an extensive review of eastern Oregon diatomites but omitted the Christmas Valley deposits. Wagner (1969) made brief mention of the production of cat litter at this site.

Hampton (1964) studied ground water in the Fort Rock basin and mapped and described several important rock units in detail for the first time. He included the diatomites which underlie much of the basin floor with several volcaniclastic bodies which crop out along the basin margins within the Fort Rock Formation. He designated the exposure in a ravine on the west side of Seven Mile Ridge as the type section (NE¼SW¼ sec. 33, T. 27 S., R. 17 E.). This outcrop is now largely submerged beneath the waters of Pettus Lake, a small, man-made reservoir which fills much of the ravine. Diatoms from this section were dated as late Pliocene in age by K.E. Lohman (*in* Hampton, 1964). Substantial improvements have been made in correlating nonmarine Pliocene rocks with the marine type section since Hampton's work was published. The late Pliocene as used by both Lohman and Hampton should now be considered equivalent to the entire Pliocene (= Blancan mammal stage), which began approximately 5 m.y. B.P.

The Picture Rock Basalt underlies the Fort Rock Formation and was dated by K-Ar methods as 6.9±0.9 m.y. B.P. A plagioclase separate from pumice within the Peyerl Tuff yielded a K-Ar age of 4.59±0.89 m.y. (Fiebelkorn and others, 1982). According to Hampton (1964), the Peyerl Tuff unconformably overlies the Hayes Butte Basalt, which in turn overlies the Fort Rock Formation. However, Peterson and McIntyre (1970) were unable to distinguish the Hayes Butte Basalt from the Paulina Basalt, which is younger than the Peyerl Tuff. At the western edge of the basin, they did map two small areas where the Peyerl Tuff directly overlies tuffaceous sandstones which may correlate with the Fort Rock Formation.

If the diatom age and the correlation and dating of the Peyerl Tuff are taken at face value, the Fort Rock Formation must be, in general, of early Pliocene age. The diatom age is poorly documented, and further work is clearly in order. Radiometric dating of the basalt capping the Table Rock complex would also clarify the age relationships of this unit. Here we refer to the Fort Rock Formation as early Pliocene in age, while recognizing that further work may demonstrate that it is actually late Miocene in age.

Hampton regarded the Fort Rock Formation as flat-lying, resting unconformably on the folded lavas of Picture Rock Basalt and being overlain in turn by the Hayes Butte Basalt.

Walker and others (1967) separated out the palagonitic tuffs and breccias of the marginal eruptive centers as a discrete map unit but continued to include the diatomites within a map unit dominated by tuffaceous sandstones and other volcaniclastic lithologies. Their cross-section shows this latter unit in conformable contact with the underlying basalts and indicates that these rocks were also involved in the folding along the southern basin margin.

Peterson and Groh (1963) and Heiken (1971) studied several of the volcaniclastic eruptive centers within and surrounding the Fort Rock basin, including Table Rock and Seven Mile Ridge. They ascribed most features observable at these centers to primary eruptive processes. Heiken and others (1981) published a field guide to several of these centers and discussed the Table Rock complex in some detail.

Pleistocene lake features within the basin were mapped by Forbes (1973). Allison (1979) summarized his own extensive work on these Pleistocene lake features and included some important observations on the underlying rocks.

METHODS

Over 100 shallow holes 1.5 to 14 m (5 to 46 ft) deep were drilled with an auger drill and logged on Oil-Dri's plant property and mining claims in the center of the southwestern part of the Fort Rock Basin. This drilling covered almost 5.2 km^2 (2 mi^2) and helped to supplement observations made on the limited surface exposures of diatomite in the area.

Drilling was conducted on the following sections of T. 27 S., R. 16 E.: N½ sec. 23; N½ sec. 14; SE¼NW¼ sec. 15; NE¼SW¼ sec. 15; S½SE¼ sec. 21; W½SW¼ sec. 27; S½ sec. 28. Five additional holes were drilled along the boundary between SE¼ sec. 32, T. 27 S., R. 17 E., and NE¼ sec. 5, T. 28 S., R. 17 E.

Two surface exposures were measured with a Jacob staff

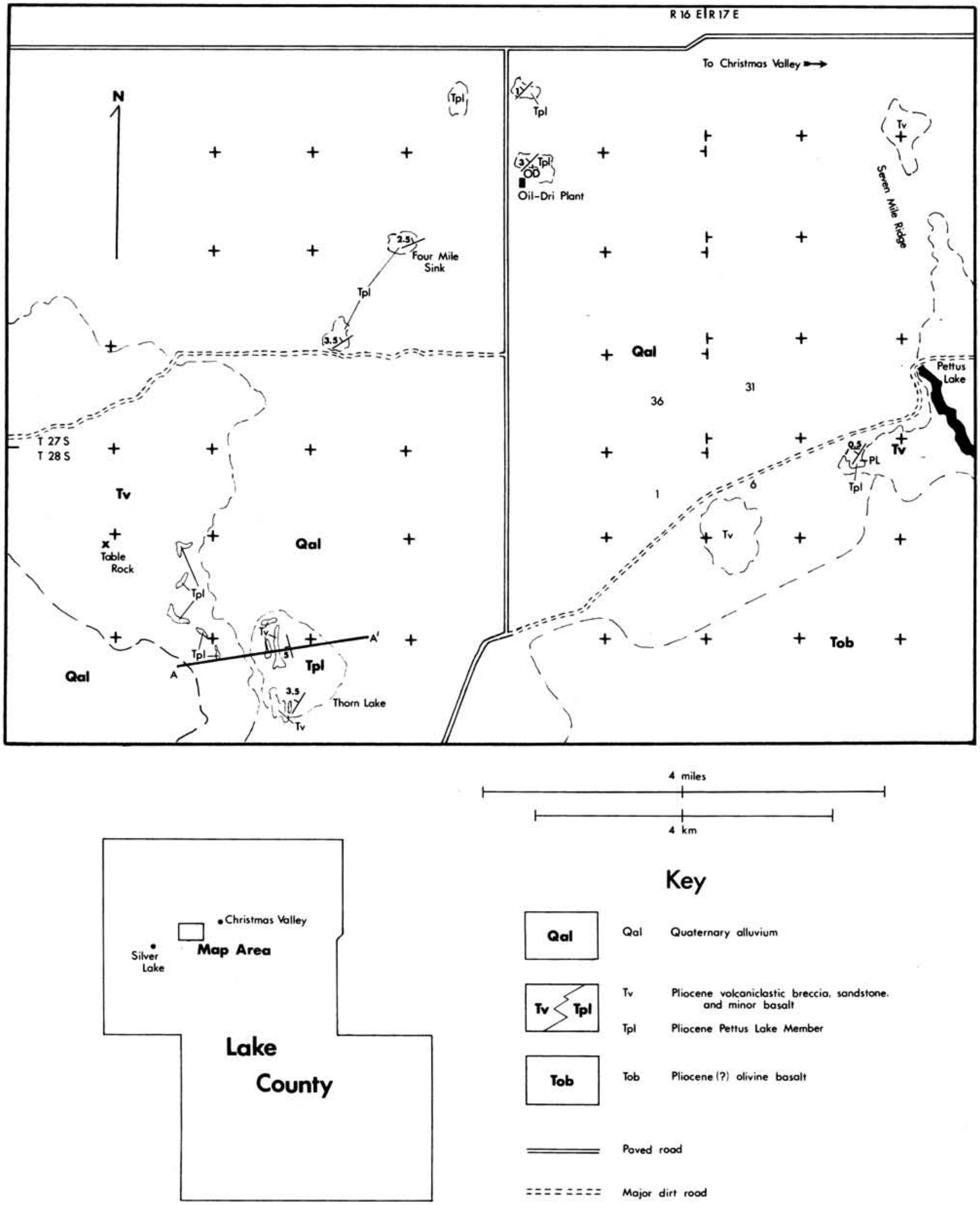


Figure 1. Geologic sketch map of part of southwestern Fort Rock basin. Units Tv and Tpl are part of Fort Rock Formation of Hampton (1964). Unit Tob is partial equivalent of Picture Rock Basalt. Unit Tob contact modified after Walker and others (1967). "PL" indicates location of type section of Pettus Lake Member, "OD" indicates location of supplementary section. Two attitudes within Thorn Lake blowout depression were measured on volcaniclastic breccia beds (unit Tv) and are offset slightly to the east for the purpose of clarity. Letters "A" and "A'" indicate end points of cross-section presented in Figure 8. Crosses indicate corners of sections. Map centered on 44° 10' N., 121° 48' W.

Figure 2. Oil-Dri's Christmas Valley plant, looking south. Absorbent products are currently being produced from crushed diatomite at this plant. Oil-Dri is one of largest employers in Fort Rock basin.

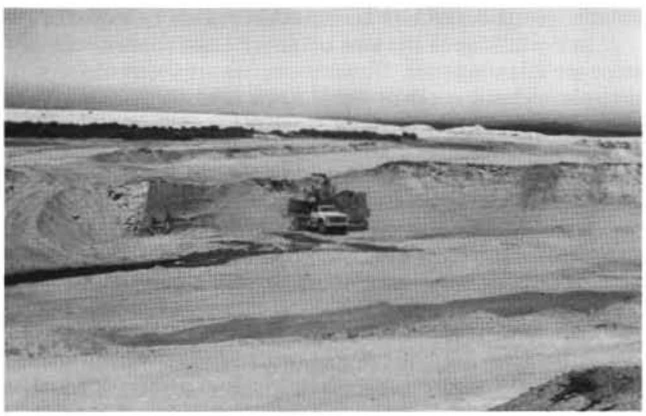


Figure 3. Oil-Dri pit, looking north. Diatomite is quarried along pervasive north-south joint set. OD section was measured at south end of pit, just to left of photograph.

and described in detail. These sections are presented graphically in Figure 4.

The local geology was mapped on aerial photographs and transferred onto a U.S. Department of Agriculture property map that served as the base map for Figure 1. Five of the attitudes indicated on Figure 1 were determined by using a transit and stadia rod on marker beds within blowout depressions and excavations. On two separate surveys within the Oil-Dri plant pit, we were able to repeat our dip determinations to within one tenth of one degree. The dips indicated in Figure 1 have been rounded off to the nearest half a degree, a level of accuracy we consider significant when dealing with gently deformed strata. Using a hand compass, we measured two additional attitudes of exposed breccia layers interbedded with diatomite in the floor of Thorn Lake.

STRATIGRAPHIC NOMENCLATURE

In his description of the Fort Rock Formation, Hampton (1964) considered diatomite a constituent volumetrically less significant than tuff. Our examination of surface outcrops, coupled with extensive shallow drilling, indicates that in the center of the basin diatomite makes up 90 percent or more of the unit in question, with the remaining 10 percent composed primarily of friable, tabular layers of pumice and volcanic ash. We feel that separating the diatomite-dominated part of the section from that composed primarily of more resistant volcaniclastic rocks will serve to greatly clarify stratigraphic relationships in this area. Such a division also neatly separates rocks which are of economic interest (to us) from those which are not.

We propose the new Pettus Lake Member to include the diatomite-dominated rocks of the Fort Rock Formation. The exposure at SE¼NW¼ sec. 5, T. 28 S., R. 17 E. (Figure 1) is here designated the type section (see Figure 4). This exposure is on Bureau of Land Management (BLM) land and is readily accessible. Contact relationships with the volcaniclastic breccia of Seven Mile Ridge are well exposed, and the stratigraphy is similar to that described by Hampton (1964) from the type section of the Fort Rock Formation. A supplementary section from the Oil-Dri pit is probably more representative of rocks in the center of the basin and is also included here.

The new member represents a subdivision of the informal unit mapped by Walker and others (1967) as Tst. The remainder of that unit is here grouped with the palagonitic tuff those authors mapped as QTps and throughout this paper will be collectively referred to informally as the volcaniclastic rocks of Table Rock or Seven Mile Ridge.

STRATIGRAPHY

The Pettus Lake Member of the Fort Rock Formation as defined here consists of white, pale-orange, or pale-gray thickly bedded diatomite with irregularly spaced, tabular interbeds of volcanic ash and pumice, many of which are bioturbated. Layers within the member interdigitate to the east and west with the matrix-supported volcaniclastic breccias and well-cemented tuffaceous sandstones and conglomerates of Seven Mile Ridge and Table Rock (Figure 1). Contact relationships to the north and south of the mapped area are obscured by alluvial cover.

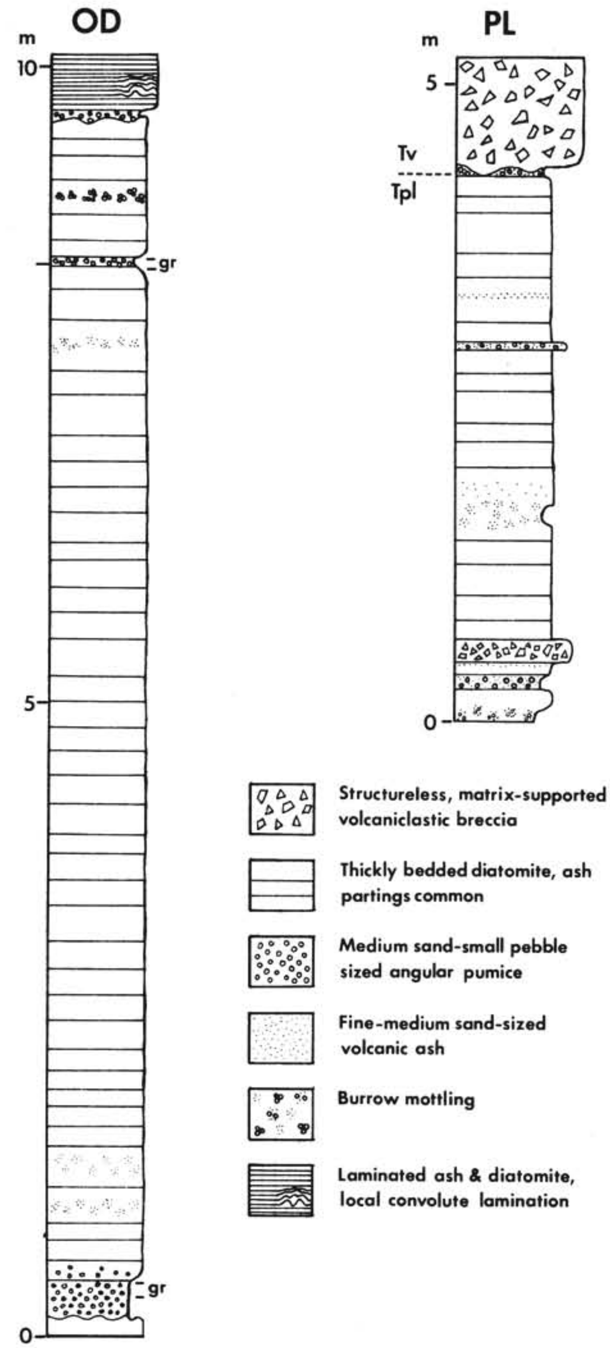
The basal contact of the member is not exposed at the surface anywhere within the basin. Drilling logs from water wells nearest the type section indicate that the diatomites overlie the Picture Rock Basalt. From current information it is not clear whether this contact is conformable or unconformable.

The Pettus Lake Member is conformably overlain by volcaniclastic breccia of Seven Mile Ridge at the type section. Throughout much of the basin, the member is overlain unconformably by a thin veneer of loosely consolidated material.

Diatomite was recorded in logs published by Hampton (1964) from six water wells drilled in the southwestern portion of the Fort Rock basin. Residents of Christmas Valley commonly report diatomite in the bottom of excavations dug for the basements of buildings. Allison (1979) recorded diatomaceous beds in Fossil Lake in the eastern part of the basin which may correlate with the Pettus Lake Member. These diatomaceous beds occur below the major disconformity at the base of the upper Pleistocene lake sequence. The Pettus Lake Member thus probably underlies most of the floor of the Fort Rock basin.

Two stratigraphic sections are presented in Figure 4. The type section (PL) immediately west of Seven Mile Ridge and Pettus Lake characterizes the unit at the basin margin, while the plant section (OD) is more typical of the rocks in the center of the basin. The two sections cannot be correlated. The PL section may be stratigraphically below the OD section, but our data are inconclusive.

By volume, diatomite is the vastly predominant lithology in the central part of the basin. When the attitude of the beds in the Oil-Dri pit is projected to the southeast across the plant property (assuming that no intervening faults or folds are present), it appears that approximately 91 m (300 ft) of the Pettus



Lake Member are truncated by the angular unconformity underlying the thin veneer of loose material penetrated by our drilling. Our drilling sampled approximately 50 percent of the section southeast of the pit, and 8.6 percent of the material proved to be ash and pumice, the remainder diatomite. Although our drilling system did not effectively sample layers much less than 15 cm (6 in) thick, this figure compares closely to the 9.7 percent ash and pumice by volume recorded for the exposed face in the Oil-Dri pit. Water-well drilling logs published by Hampton (1964) record as much as 200 m (655 ft) of diatomite in this part of the basin.

To the east and west, the Pettus Lake Member grades into volcaniclastic rocks (Figure 5). In the floor of Thorn Lake (actually a blowout depression), matrix-supported, volcaniclastic breccia layers 1 m (3 ft) or less thick are interbedded with diatomite (Figure 1). These layers are tabular on a small scale but pinch out laterally over a distance of 100 m (300 ft) or more. Allison (1979) considered these breccias to be clastic dikes. Two of the layers which were examined closely by the senior author of the present paper appear to dip gently to the west, with strikes roughly parallel to color banding in the adjacent diatomite. No splays into the diatomite were observed. We consider these two layers to be in depositional contact with the diatomites, although the possibility that they are actually gently discordant clastic dikes cannot be excluded.

← Figure 4. Measured stratigraphic columns of Pettus Lake Member, Fort Rock Formation. Section PL is type section of Pettus Lake Member, measured in face scraped off by skiploader on low hill immediately to east of secondary dirt road, SE¼NW¼ sec. 5, T. 28 S., R. 17 E. Supplementary section OD was measured in south end of Oil-Dri's pit just north of plant, NW¼NW¼ sec. 23, T. 27 S., R. 16 E. Note that OD section is on private property and may not be examined without permission from Oil-Dri Corporation of America. Clasts within volcaniclastic breccia are 90 to 95 percent glassy, vesicular basalt and 5 to 10 percent pumice. Symbol "gr" indicates intervals in which pumice exhibits graded lamination.

In the hillside to the west of Thorn Lake contact relationships are unambiguous. Diatomite lenses are interbedded with the volcaniclastic rocks of Table Rock as much as 30 m (90 ft) above the present basin floor (Figure 6). Heiken and others (1981) noted these diatomite lenses and suggested that they "were deposited in a crater lake apart from the larger basin" (p. 133). Structural evidence for extensive erosion of the Pettus Lake Member is presented below (see GEOLOGIC STRUCTURE). However, outcrops of the diatomite in the hillside appear to extend beyond the margins of the vent (vent 4) which Heiken and others (1981) assumed impounded the lake. We therefore suggest instead that these diatomite lenses represent erosional remnants which were formerly connected to the main body of a thicker sequence of lake sediments, a conclusion supported by the diatom flora (see PALEONTOLOGY).

Also noteworthy in this regard is the presence of a large

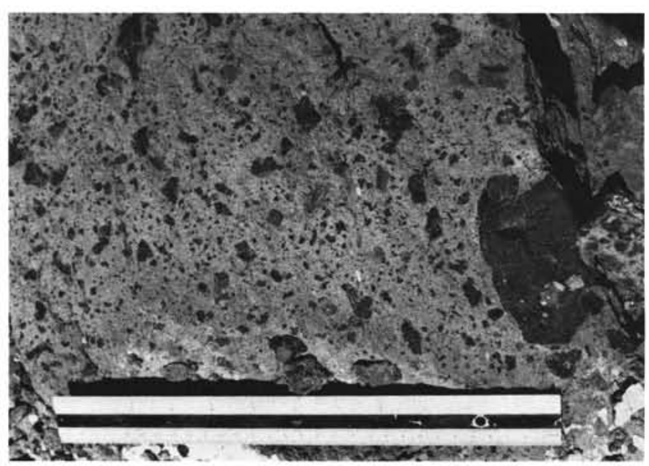


Figure 5. Matrix-supported volcaniclastic breccia of Seven Mile Ridge, from near dam at north end of Pettus Lake. Dark, angular clasts are glassy, vesicular basalt. This structureless breccia unit is typical of those found at both Seven Mile Ridge and Table Rock. Average clast size decreases to west of this locality, where breccias of Seven Mile Ridge interfinger with Pettus Lake Member of Fort Rock Formation (Heiken, 1971). Ruler = 30.5 cm (1 ft).

sedimentary dike reported by Allison (1979) in Four Mile Sink (a blowout depression in the SE¼SE¼ sec. 21, T. 27 S., R. 16 E.). This dike strikes to the northeast and is up to 2 m (6 ft) wide, tapering both to the northeast and southwest. Several small- to moderate-sized splays 0.5 m (1.6 ft) wide extend into the surrounding diatomite. The dike is composed of matrix-supported volcaniclastic breccia similar to that observed at Table Rock and Seven Mile Ridge. Angular fragments of diatomite are scattered throughout the dike and show no evidence of alteration. There is no baked zone present along the margins of the dike. The texture of this material, when examined in thin section, confirms that it was injected as fluid-saturated sediment rather than as molten magma.

This dike is located more than 3 km (1.8 mi) from the nearest exposure of the volcaniclastic rocks of Table Rock. As no similar material was encountered in any of the shallow drill holes nearby, the dike was apparently injected from some depth. This illustrates how extensively interbedded these two lithologies are, at least at depth.

A similar relationship prevails at the type locality of the Pettus Lake Member (Figure 4). Five shallow holes 5 to 13 m (16 to 43 ft) deep were drilled to the east of the type section. Breccia layers 0.2 to 5 m (0.7 to 15 ft) thick are interbedded with diatomite layers up to 1 m (3 ft) thick along this transect. This interfingering was also noted by Hampton (1964) in his description of the Fort Rock Formation.

GEOLOGIC STRUCTURE

The Pettus Lake Member underlies much of the southern Fort Rock Basin but is generally poorly exposed. Using a transit and stadia rod, we were able to determine the attitudes of marker beds in five excavations and blowout depressions (Figure 1). The two additional attitudes recorded from breccia beds in Thorn Lake were determined with a hand compass.

Allison (1979) noted the presence of an extensive disconformity between the diatomites and overlying lake sediments of late Pleistocene age. Our data indicate that this contact is actually an angular unconformity. The diatomites have been

Figure 6. View of Table Rock from Thorn Lake blowout depression. Arrows indicate outcrops of Pettus Lake Member which are above present-day basin floor (basin floor is approximately at lowermost growth of trees). We interpret these diatomite outcrops as erosional remnants of what was formerly a much thicker diatomite sequence. Outcrop on left was sampled for siliceous microfossils. Table Rock is remnant of Pliocene tuff cone capped by basalt which was once ponded in crater at center of cone (Heiken and others, 1981).

Figure 7. Four Mile Sink blowout depression (SE¼SE¼ sec. 21, T. 27 S., R. 16 E.), looking due east. Dark diatomite layer (arrow) illustrates northern component of dip of beds at this locality. Actual attitude is N. 57° E. 2.5° NW. Dipping diatomite beds are overlain unconformably by thin veneer of unconsolidated material.

systematically deformed (Figure 7) and strike north to northeast, with a west or northwest dip of 0.5° to 5°. This finding is surprising, as aerial photos of the basin give no hint of such an underlying structure. Apparently these beds are so uniformly soft that they were evenly planed off during some erosional event. Our drilling encountered only a thin veneer (0.2 to 3 m [0.7 to 9 ft] thick, average 1 m [3 ft] thick) of unconsolidated material resting unconformably on this erosional surface.

The presence of undeformed younger lake terraces on both Table Rock and Seven Mile Ridge adds to the impression that these volcaniclastic bodies are structurally flat-lying. In fact, the high initial dips of the volcaniclastic rocks preclude direct detection of gentle folding, but the intimate interfingering of these units with the diatomite suggests that they must be deformed in like fashion.

Hampton's (1964) assumption that folding ceased with deformation of the basalt underlying these units is clearly incorrect. Neither is it clear, however, that the Pettus Lake Member conformably overlies this basalt, as depicted in the cross-section of Walker and others (1967). We do not have enough data to rule out this interpretation, but the possibility that folding was initiated prior to and continued throughout the time of deposition of the diatomaceous sediments should at least be considered.

This structural information also comes to bear on the interpretation of the geomorphic evolution of this basin. Sometime between the early Pliocene when the sediments were deposited and the late Pleistocene when the lake terraces described by Forbes (1973) and Allison (1979) were developed, an open drainage system must have operated in this area. A tremendous volume of diatomite must have been removed to produce the extensive angular unconformity overlain by a thin veneer of alluvium which we observe.

The volcaniclastic rocks of Table Rock and Seven Mile Ridge were at least partially interbedded with these diatomites and were probably exhumed during the erosional event described above (Figure 8). Peterson and McIntyre (1970) suggested a similar interpretation for similar features southwest of our study area in an adjacent basin.

A fault is present at the north end of the Oil-Dri plant pit. The fault is vertical and strikes N. 70° E. A relative vertical displacement of at least 1.6 m (5 ft), with the north side upthrown, is indicated by drilling information. A sheared zone

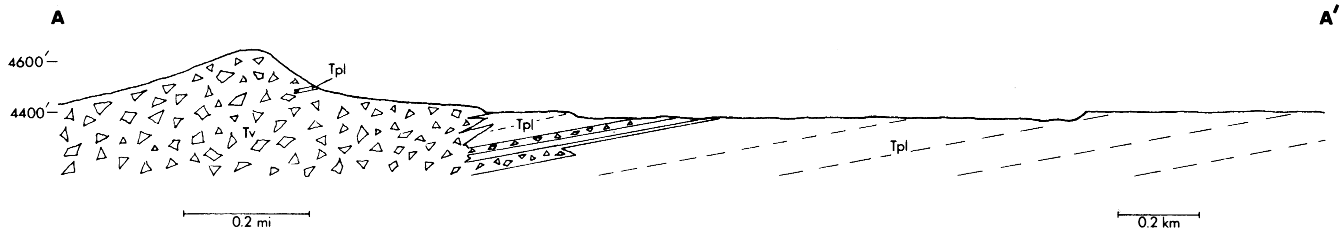


Figure 8. Simplified cross-section through southern end of Table Rock complex and Thorn Lake showing our interpretation of stratigraphic relationship between units Tv and Tpl. No attempt is made to show faulting. Dashed lines indicate dip of bedding within the diatomite. Unit Qal is not shown. Vertical exaggeration = 2×.

3 m (9 ft) wide is evident along the fault. Convolute lamination and numerous small sedimentary dikes emanating from dismembered pumiceous sandstone beds clearly point to a water-saturated condition for the sediments at the time of faulting.

Also present in the area is a pervasive joint system which greatly facilitates mining the diatomite. The predominant joint set is vertical and strikes roughly north-south, with joints generally spaced 1 m (3 ft) apart. In some places thin veinlets of gypsum precipitated along these joints.

PALEONTOLOGY

Fish fossils are fairly common from 1 to 5 m (3 to 15 ft) above the base of the Oil-Dri pit section. We recovered remains of at least seven individuals from six stratigraphic horizons in approximately one hour. All specimens are disarticulated to some degree, and no complete skulls were recovered. This suggests the presence of an active scavenging bottom fauna.

Although the most information is obtained by dealing with diatoms at the species level, the taxonomic treatment required for such an analysis is far beyond the scope of the present study. Relative abundances of diatom genera do help to characterize the ancient lake in which these sediments were deposited, however. Generic identifications were made using Moore (1937), Patrick and Reimer (1966, 1975), and VanLandingham (1964, 1967). No attempt was made to sort out the genera of the family Fragilariaceae. Some members of this family are extremely small, and the group may be somewhat underrepresented in the counts.

Forty-seven drill cutting and surface samples were examined microscopically to evaluate their potential for the production of filter aids. Striking changes in the diatom flora became evident during this evaluation. Samples from six levels within the Oil-Dri pit and two samples from the PL section were prepared in order to document these fluctuations (Table 1). Strew mounts were prepared of disaggregated material, with care taken to obtain a representative distribution of particle sizes. Two slides were prepared per sample, and 100 specimens were counted on each slide under 400× magnification.

The genera listed in Table 1 form an association typical of fresh-water deposits. One species which could be identified, *Stephanodiscus niagarae* Ehrenberg, is common in Klamath Lake today (Moore, 1937).

The centric diatoms listed are all planktonic forms. Many, but not all, of the Fragilariaceae are also planktonic. The remaining pennate genera, including several large forms, are predominantly benthic. Planktonic forms thus exhibit much higher relative abundances than do benthic forms in the samples examined, suggesting that the water within the lake was relatively deep and circulated freely (Patrick, 1948; Patrick and Reimer, 1966).

Further, the predominance of centric diatoms hints that the lake may have been oligotrophic, i.e. relatively nutrient-poor. Stockner and Benson (1967) suggested that a ratio of members of the Fragilariaceae to all centric diatoms of less than 1:1 in lake sediments may be an indicator of oligotrophic conditions. This seems to hold good for many, but not all, modern lakes (Birks and Birks, 1980). Abundant representatives of the genus *Cyclotella* are also characteristic of oligotrophic lakes (Rawson, 1956; Stockner and Benson, 1967).

If conditions were indeed oligotrophic, lack of silica was clearly not one of the factors which limited diatom growth, because ubiquitous volcanic ash and pumice fragments would have provided a ready source of dissolved silica. Very little organic carbon is obvious in the stratigraphic sections described here, although that may merely reflect oxidizing bottom conditions in the ancient lake rather than a dearth of organic matter. Nitrogen and phosphorus are two nutrients which impose important constraints on diatom growth, but their presence is difficult to evaluate in ancient deposits.

The striking fluctuations in the relative abundances of the three genera of centric diatoms are less easily explained. Major changes in the relative abundances of particular planktonic diatom taxa can be produced by fairly small changes in a particular environmental parameter, such as the phosphorous content of the water or the density of grazing zooplankton (Stockner and Benson, 1967; R. Castenholz, personal communication, 1982). Little can thus be concluded in regard to these fluctuations, other than that a dynamic ecological system operated within the lake.

Diatoms also yield important information about the stratigraphic relationships of the Pettus Lake Member. A grab sample from one of the diatomite lenses in the hillside west of Thorn Lake (Figure 6) was examined microscopically. No sponge spicules were counted, and the diatoms were represented as follows: *Melosira*, 39 percent; *Cyclotella*, 37 percent; *Stephanodiscus*, 2.5 percent; family Fragilariaceae, 20 percent; and all other pennate diatoms, 1.5 percent. Such a flora dominated by planktonic taxa strongly suggests deposition in a lake exhibiting free circulation, rather than in a shallow pond within a volcanic crater, and thus supports our contention that the diatomite lenses are erosional remnants of a formerly more extensive lake deposit.

Sponge spicules are present throughout the OD section (Table 1). Although some specimens are ornate, little can be said about their environmental significance. Sponge spicules are consistent with oxygenated bottom conditions within the lake, however, which are also indicated by the disarticulated fish fossils and bioturbated ash layers.

DEPOSITIONAL ENVIRONMENTS

The extensive tabular beds of diatomite containing a fresh-water diatom flora clearly point to a lacustrine origin for the Pettus Lake Member of the Fort Rock Formation. In the center of the basin, interbedded ash and pumice layers are tabular and friable, with no observable paleocurrent in-

Table 1. *Relative abundances of siliceous microfossils from selected samples of the Pettus Lake Member*

	Samples*								
	OD 0.0	OD 0.9	OD 1.8	OD 3.6	OD 5.5	OD 8.5	PL 1.4	PL 1.7	Total
Centric diatoms**									
Cyclotella	128	12	150	5	25	89	12	2	423
Melosira	2	3	19	8	102	9	98	176	417
Stephanodiscus	40	106	1	85	12	24	58	20	346
Pennate diatoms									
Family Fragilariaceae	21	55	21	51	42	68	17	1	276
Cocconeis	—	—	—	1	2	1	2	—	6
Cymbella	2	6	1	1	2	1	4	—	17
Entomoneis	—	—	—	3	—	—	—	—	3
Epithemia	1	—	1	7	2	—	—	—	11
Eunotia	—	—	—	—	1	—	—	—	1
Gomphonema	—	—	—	—	2	—	1	—	3
Navicula	—	1	—	11	4	1	—	—	17
Surirella	1	2	2	3	—	—	—	—	8
Other pennates	3	5	2	18	5	5	8	1	47
Sponge spicules***	2	10	3	7	1	2	—	—	25
Total	200	200	200	200	200	200	200	200	1600

* Sample numbers represent height above base of respective section in meters.
** Counts are of single valves in which more than half of the valve was preserved.
*** Counted only if the tip of the spicule was present.

dicators. These beds probably originated by the settling of volcanic fragments which were erupted directly into the lake rather than transported by streams. It is also noteworthy that these volcaniclastic layers exhibit two distinct lithologies. The pumice layers are composed of gray-blue, medium- to coarse-grained, sand-sized particles of frothy pumice. The volcanic ash layers, on the other hand, are composed of dark, fine, sand-sized particles, many of which are volcanic rock fragments and broken mineral grains. Perhaps two different types of eruptions are recorded by these layers: one type primarily involved juvenile material, the second involved extensive destruction of pre-existing rock. Separate eruptive sources may also be indicated.

The friable sandstone layers at the type section (PL) are generally more heterogeneous than those in the center of the basin. This mixture of grains may reflect some influx from streams, although no sedimentary structures are present which suggest that these layers were deposited above lake level. The presence of interbedded volcaniclastic breccias also suggests that the margin of the lake may have been nearby. The two diatom samples from this section, however, are strongly dominated by planktonic forms (Table 1) and provide no hint of the presence of rooted vegetation or shallow-water conditions. Apparently either the lake had a fairly abrupt margin or the volcaniclastic rocks of Seven Mile Ridge were largely erupted under water.

Hampton (1964) interpreted the matrix-supported volcaniclastic breccias as mudflow deposits, while Heiken (1971) and Heiken and others (1981) considered them phreatic eruptive units. The latter authors based their case for a "hot" origin on the observation that the matrix of these breccias is altered to palagonite.

Two other lithologies are common within the Table Rock complex: (1) fine, graded, tabular laminae of fine- to medium-grained tuff; and (2) cross-bedded couplets of coarse, sand-sized fragments (tops) and reverse-graded tuff breccias or conglomerates (bottoms). Discrete units of these lithologies exhibit cut-and-fill contacts with each other and with matrix-supported breccias throughout the Table Rock complex. Heiken and others (1981) interpreted the graded, finely laminated lithofacies as representing direct air-fall deposition of tuff. They reported antidune structures in the cross-bedded lithofacies and ascribed the origin of these units to deposition by base surges.

Missing from the above descriptions and our own discussion of the Pettus Lake Member are any indications of shoreline conditions along the margins of the early Pliocene lake. If the lake margins were fairly abrupt, any resulting beach deposits would occur in a very narrow band and might easily be overlooked. Stream runoff from the small area occupied by the Table Rock complex might not have produced deltaic deposits to any significant extent. Nonetheless, a careful search for lithofacies characteristic of such marginal environments holds out the most promise for acquiring a detailed understanding of the conditions under which the tuff rings of the Fort Rock basin were erupted.

CONCLUSIONS

(1) The diatomite-dominated lower Pliocene rocks of the Fort Rock basin can be mapped as a separate member of the Fort Rock Formation, here named the Pettus Lake Member. (2) These beds have been systematically deformed and dip 0.5° to 5° to the west or northwest. (3) A thin veneer of alluvium overlies an unconformable erosional surface developed on the Pettus Lake Member beneath much of the basin floor. (4) Sometime between the early Pliocene and latest Pleistocene, an open drainage system operating in the basin eroded a tremendous quantity of diatomite. (5) The diatomites interdigitate to the east and west with volcaniclastic rocks that were at least partially exhumed by the above erosional event. (6) Two distinct types of eruptions may be documented by numerous thin volcaniclastic layers within the Pettus Lake Member. One type involved abundant juvenile material and produced pumice layers, the other expelled rock and mineral fragments and produced fine-grained ash layers. Different eruptive sources may also be recorded by these volcaniclastic layers. (7) The diatomaceous sediments were deposited in a relatively deep, fresh-water, possibly oligotrophic lake with oxygenated bottom conditions.

ACKNOWLEDGMENTS

We express special thanks to Rudolf C. Valenta of the Oil-Dri Corporation of America for directing the assessment work and encouraging the preparation of this publication. The Oil-Dri Corporation of America kindly allowed us to use information collected in the course of the assessment work. Richard Castenholz, Biology Department, University of Oregon, provided helpful information concerning diatom ecology. Jane Gray, Biology Department, University of Oregon; Thomas Brikowski, Geology Department, University of Oregon; N.V. Peterson, Oregon Department of Geology and Mineral Industries; and Rudolf C. Valenta reviewed the manuscript.

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Preliminary report on sulfide deposits off Oregon coast now available from USGS

Since 1978, U.S. Geological Survey (USGS) photographic and submersible studies in the eastern Pacific Ocean have identified six polymetallic sulfide deposits and associated hydrothermal springs on the East Pacific Rise and the Juan de Fuca Ridge west of the Oregon coast (*Oregon Geology*, v. 44, no. 6, p. 70). Preliminary results of these studies have been released by the USGS as Open-File Report 82-200A, *Geologic Setting of Massive Sulfide Deposits and Hydrothermal Vents along the Southern Juan de Fuca Ridge*, by William R. Normark, Janet L. Morton, and John R. Delaney; Open-File Report 82-200B, *Preliminary Description of Massive Sulfide Samples from the Southern Juan de Fuca Ridge*, by Randolph A. Koski, Robert Goodfellow, and Robin Bouse; and Open-File Report 82-200C, *Preliminary Description of Basalt from the Southern Juan de Fuca Ridge*, by Jacqueline S. Eaby and David A. Clague.

All of these open-file reports are available from the Open-File Services Section, Branch of Distribution, USGS, Box 25425, Federal Center, Denver, CO 80225. Cost of 82-200A and B is $2.75 each; 82-200C costs $2. □

New wildlife book available

Scientists of three federal and state agencies have collaborated to produce a 515-page reference book titled *Natural History of Oregon Coast Mammals.* The manual describes 65 land mammals and 31 marine mammals, including data on their distribution, habits, food, reproduction, and economic status. It also describes each animal's habitat requirements so that land managers can consider them in carrying out responsibilities to balance resource uses under sustained-yield, multiple-use management policies.

A chapter on vegetation and habitats was authored by Jerry F. Franklin of the Pacific Northwest Forest and Range Experiment Station. Another experiment station scientist, C.T. Dyrness, wrote a chapter on geology and soils of the Oregon coast. The 337-page section about land mammals was written by Chris Maser, wildlife biologist for the Bureau of Land Management. The marine mammal section was authored by Bruce R. Mate of Oregon State University's Marine Science Center.

This publication is available over-the-counter on the 15th floor of the BLM State Office, 825 NE Multnomah Street, Portland; or from the Pacific Northwest Range and Experimental Station, 809 NE 6th Avenue, Portland. □

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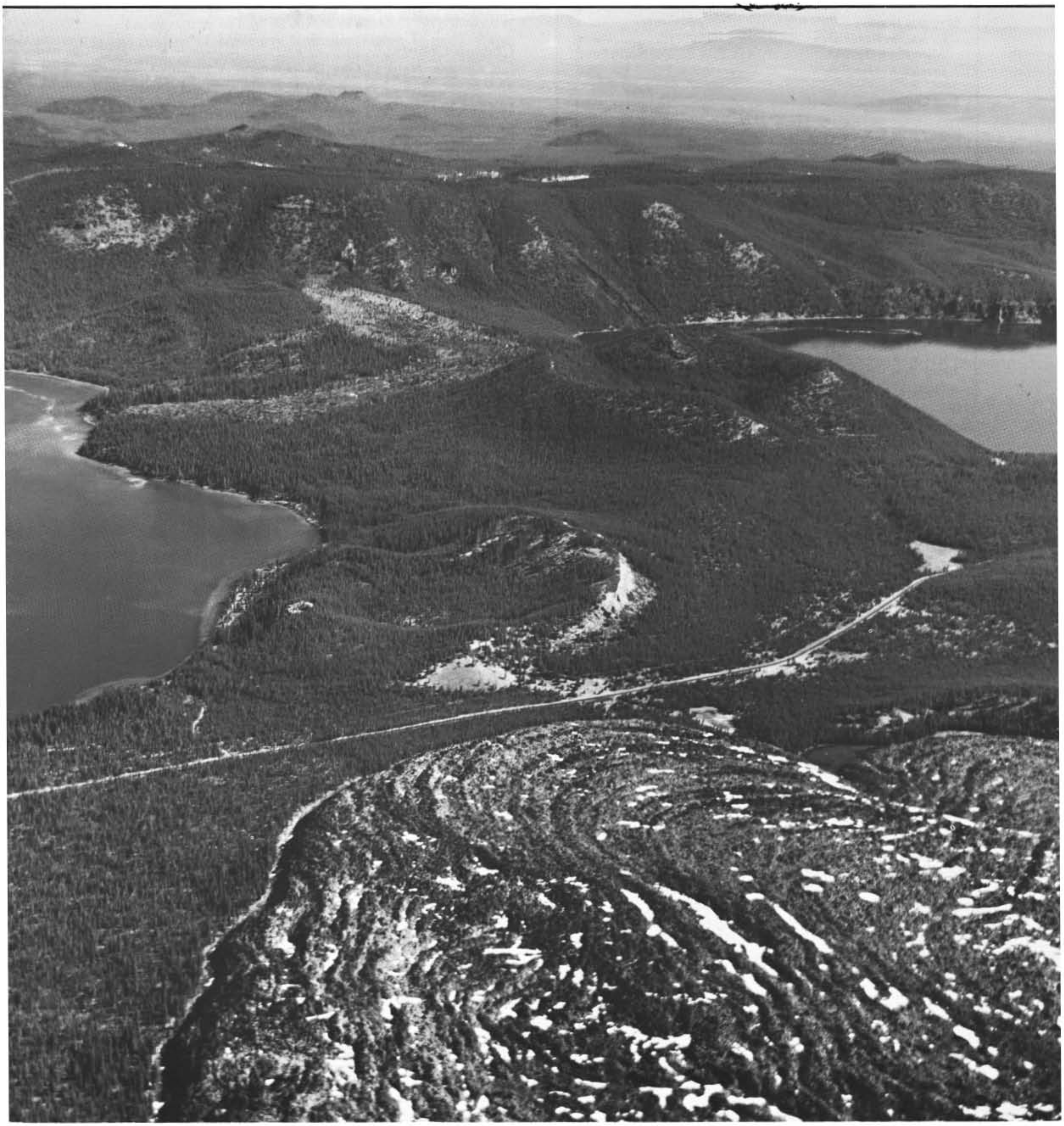

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COVER PHOTO

View to the northeast of the caldera of Newberry Volcano. The paper beginning on next page discusses the geothermal potential of this Quaternary volcano. Features visible in this photo include Big Obsidian Flow in the foreground; Paulina Lake on the left; East Lake on the right; Little Crater, central pumice cone, and interlake obsidian flow in the middle; and north wall of the caldera behind. In the background are some of the 400 cinder cones and fissure vents that dot the flanks of Newberry.

OIL AND GAS NEWS

Columbia County

Reichhold Energy Corporation drilled Adams 34-28 to a total depth of 2,572 ft. The well, in sec. 28, T. 7 N., R. 5 W., was abandoned as a dry hole in September.

The company will soon spud Libel 12-14 in the Mist gas field. The proposed 2,900-ft well is to be located in sec. 14, T. 6 N., R. 5 W.. The location is half a mile from the recently completed redrill of Columbia County 4.

Clatsop County

Oregon Natural Gas Development Company's Patton 32-9 in sec. 9, T. 7 N., R. 5 W., is idle pending the decision whether to redrill.

Douglas County

Florida Exploration Company has abandoned the 1-4 well near Drain. It is not known whether the company will drill other locations.

Yamhill County

Nahama and Weagant Energy Company recently drilled Klohs 1 in sec. 6, T. 3 S., R. 2 W. The well was abandoned as a dry hole.

Recent permits

Permit no.	Operator and well name	Location	Status and depth TD = total depth (ft) RD = redrill (ft)
219	Reichhold Energy Corp.; Werner 14-21	SW¼ sec. 21 T. 5 S., R. 2 W. Marion County	Abandoned; dry hole; TD: 3,354.
220	Reichhold Energy Corp.; Crown Zellerbach 31-33	NE¼ sec. 33 T. 6 N., R. 4 W. Columbia County	Permit issued.
221	Reichhold Energy Corp.; Crown Zellerbach 44-23	SE¼ sec. 23 T. 5 N., R. 4 W. Columbia County	Permit issued.
222	Reichhold Energy Corp.; Siegenthaler 42-13	NE¼ sec. 13 T. 6 N., R. 5 W. Columbia County	Permit issued.
223	Reichhold Energy Corp.; Crown Zellerbach 14-36	SW¼ sec. 36 T. 7 N., R. 5 W. Columbia County	Permit issued.
224	Reichhold Energy Corp.; Libel 12-14	NW¼ sec. 14 T. 6 N., R. 5 W. Columbia County	Permit issued. □

CONTENTS

Newberry Volcano, Oregon: A Cascade Range geothermal prospect *

by N.S. MacLeod, U.S. Geological Survey, Vancouver, Washington, and E.A. Sammel, U.S. Geological Survey, Menlo Park, California.

INTRODUCTION

Temperatures as high as 265° C in a 932-m-deep drill hole in the caldera of Newberry Volcano (Figure 1) marked the culmination of a series of geologic and geothermal studies in central Oregon undertaken by the U.S. Geological Survey (USGS) in its Geothermal Research Program. These temperatures, easily the highest recorded in the Pacific Northwest, as well as the large volume and wide areal distribution of young silicic volcanic rocks, suggest that a large heat source underlies the volcano and that it may have a potential for electric power generation.

Many of the electric-power-producing geothermal reservoirs in the world occur in or near young silicic volcanic fields. Magma chambers that feed rhyolitic volcanism are commonly large and located in the upper crust; if the rhyolitic bodies have not cooled substantially, they offer a heat source within the range of modern drilling technology (Smith and Shaw, 1975). Basalt fields fed by narrow dikes extending from great depth are less favorable geothermal targets, although in some places such as Iceland and Hawaii they form important geothermal systems.

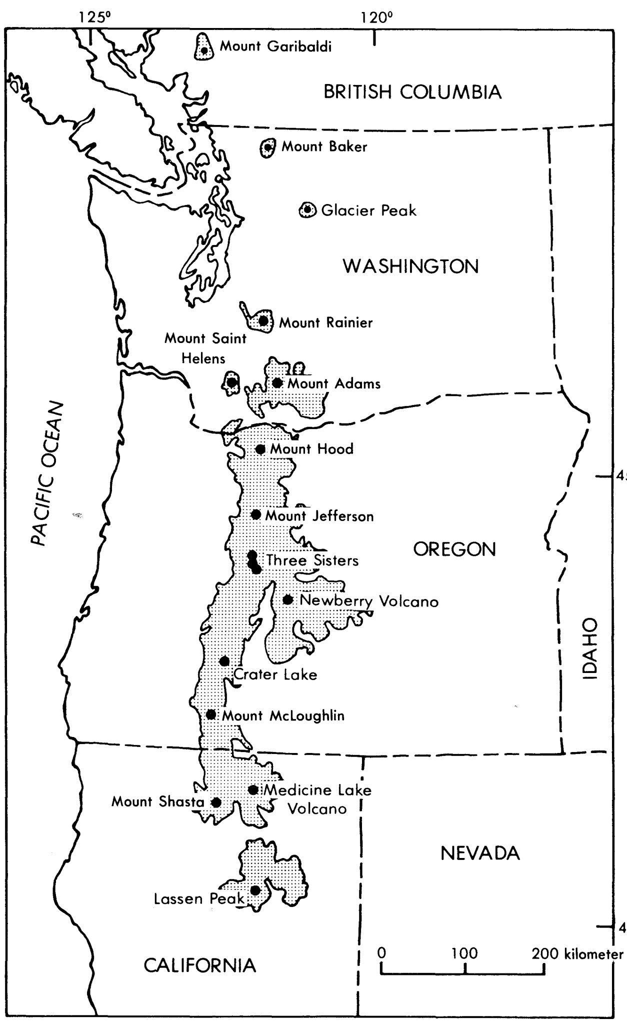

Figure 1. Major volcanic centers and areas of Quaternary volcanic rocks in the Cascade Range.

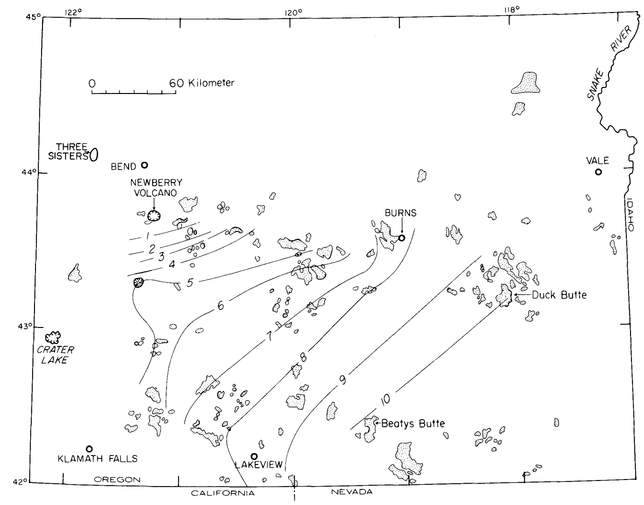

Figure 2. Age progression of silicic domal rocks (patterned) in southeast Oregon. Isochrons in increments of 1 million years. Modified from MacLeod and others (1976).

The USGS geothermal project in Oregon began with studies of young rhyolitic rocks that occur in a broad zone that extends about 320 km eastward from the Cascade Range (Figure 2). Field work by G.W. Walker suggested that the rhyolitic rocks were progressively younger toward the Cascade Range. Extensive potassium-argon (K-Ar) dating of the rhyolites by E.H. McKee confirmed this progression and showed that the rhyolites have a monotonic decrease in age from about 10 million years (m.y.) in southeastern Oregon to less than 1 m.y. near the Cascade Range in the vicinity of Newberry Volcano (Walker, 1974; MacLeod and others, 1976). This age progression suggested that geothermal resources related to young rhyolitic volcanism are most likely to occur at the west end of the rhyolite belt near Newberry. The occurrence of hot springs, fumaroles, and young obsidian flows and pumice deposits in the caldera at Newberry's summit further suggested it as a target for additional geologic and geophysical studies.

Williams (1935, 1957) and Higgins (1973) considered Newberry Volcano to be a basaltic shield with rhyolites mainly restricted to the caldera. Later mapping of the volcano, however, showed that rhyolitic domes and flows and andesitic to

* Because of similarities between Newberry Volcano in Oregon and the Medicine Lake region in California, the editors of *California Geology* solicited this article from the authors and are publishing it in the November issue of their magazine. We are printing it in *Oregon Geology* because we believe it will provide useful and interesting information to our readers as well. —*Editor*

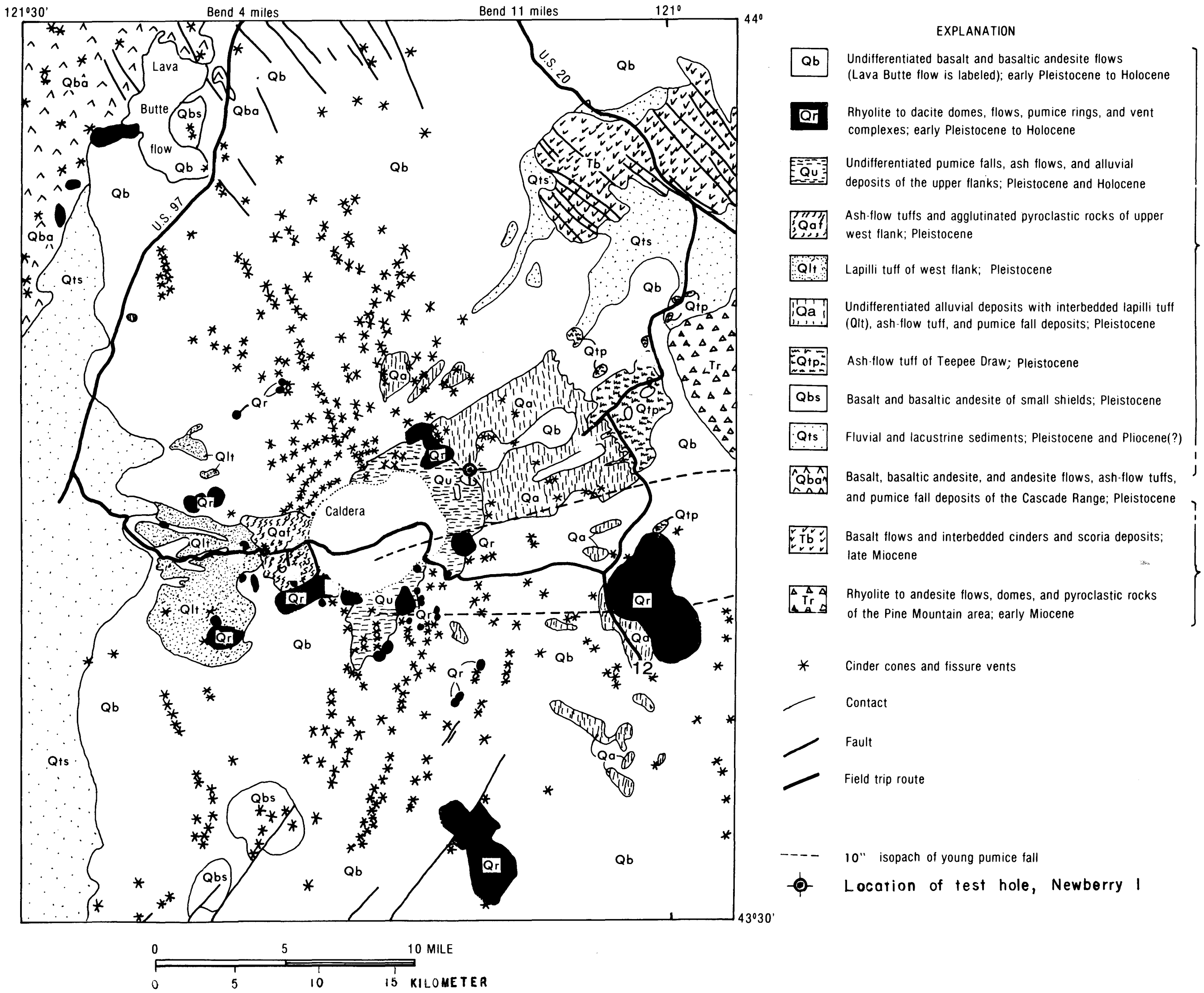

Figure 3. Geologic sketch map of Newberry Volcano. Geology of caldera is shown in Figure 4. Modified from MacLeod and others (1981).

rhyolitic ash-flow tuffs are widespread on the flanks and that the volcano has a long and complex history of volcanism that ranged from basaltic to rhyolitic (MacLeod, 1978). These encouraging indications of geothermal potential resulted in the focusing of geologic, geophysical, and water-resources investigations on the volcano and ultimately led to the drilling of two exploratory holes.

GEOLOGY

Newbery Volcano lies 60 km east of the crest of the Cascade Range in central Oregon (Figure 1) and is among the largest Quaternary volcanoes in the conterminous United States. It covers an area in excess of 1,200 km^2 and rises about 1,100 m above the surrounding terrain. The gently sloping flanks, studded with more than 400 cinder cones, consist of basalt and basaltic-andesite flows, andesitic to rhyolitic ash-flow and air-fall tuffs, dacite to rhyolite domes and flows, and alluvial sediments produced during periods of erosion of the volcano (MacLeod and others, 1981). The 6- to 8-km-wide caldera at Newberry's summit, which contains scenic Paulina and East Lakes, has been the site of numerous Holocene eruptions, the most recent of which occurred about 1,350 years ago.

Among the older rocks on the flanks of the volcano are ash-flow tuffs and associated pumice-fall tuffs, mudflows, and other pyroclastic deposits (Figure 3). They occur predominately on the east and west flanks of the volcano but probably extend completely around it and are buried by basaltic flows on the north and south flanks. Although many of the pyroclastic flows may be shoestring-type deposits that occur at only a few locations, at least four are major sheetlike deposits with considerable volume. The oldest ash-flow tuff is rhyolitic in composition and is at least 20 m thick even at places where the top is eroded and the base not exposed. Its original volume may have been more than 40 km^3. Successively younger major pyroclastic units range from rhyodacite to andesite and basaltic andesite and have estimated volumes of less than 1 km^3 to more than 40 km^3. Gravel deposits peripheral to the volcano commonly are largely composed of clasts derived from the deeply eroded pyroclastic rock sequence.

Basalt and basaltic-andesite flows and associated vents veneer the north and south flanks of the volcano. Individual flows are a few meters to 30 m thick and cover areas of less than 1 km^2 to many tens of square kilometers. The flows can be divided readily into two groups on the basis of their age relative to Mazama ash (carbon-14 age about 6,900 years) derived from Mount Mazama, 120 km to the southwest. The youngest flows, which overlie Mazama ash, have carbon-14 ages that range from 5,800 to 6,380 years. Indicated carbon-14 ages of this magnitude are generally about 800 years younger than actual ages. These youngest flows may have erupted during a much shorter period of time than the age spread indicates, inasmuch as the spread of replicate dates from individual flows is nearly as large as the spread of dates from all flows. Some of the flows that are covered by Mazama ash have surface features that suggest a rather young age, perhaps 7,000 to 10,000 years. Other flows are probably several tens or hundreds of thousands of years old. All flows sampled are normally polarized; thus none are probably older than 700,000 years.

More than 400 cinder cones and fissure vents have been identified on the flanks of Newberry; few other volcanoes contain so many. The cones and fissures are concentrated in three zones. The northwestern zone of vents is collinear with a zone of faults on the lowermost flank that extends to Green Ridge in the Cascade Range; a southwestern zone is collinear with the Walker Rim fault zone that extends south-southwest from the south flank of Newberry; and an eastern zone is a continuation of the High Lava Plains zone of basaltic vents and parallels the Brothers fault zone. Most fissures and aligned cinder cones parallel the belts in which they occur. Some aligned cinder cones and fissure vents near the summit caldera occur in arcuate zones parallel to the caldera rim and probably lie along ring fractures.

Rhyolitic domes, pumice rings, flows, and small protrusions also are common on the flanks. The larger domes are 30 to 180 m high and as much as 1,200 m across; the largest forms Paulina Peak, the highest point on the volcano, and extends 5 km southwestward from the caldera walls. Several of the larger domes have yielded K-Ar ages of 100,000 to 600,000 years. Some small protrusions on the upper southeast flank may be less than 10,000 years old.

Petrochemical and petrographic studies of the flank rhyolites have distinguished at least six groups of rhyolites on the basis of major- and minor-element compositions and proportions as well as compositions of phenocryst phases. Within each group, represented by two or more domes, compositions are virtually identical, although they occur at sites as much as 18 km apart. As it is likely that individual groups are products of extrusion at the same time from the same magma chamber, the chamber(s) at one time may have underlain large areas below the volcano.

The caldera at the summit of the volcano was formerly thought to result from drainage of the underlying magma reservoir by subterranean migration of magma or copious eruptions of basalt from flank fissures (Williams, 1957) or by tectonic volcanic collapse along fault zones that intersected at the summit (Higgins, 1973). Ash-flow tuffs and other tephra units, however, are now known to be common and voluminous on the flanks. Thus, the caldera seems much more likely to be the result of collapse following voluminous tephra eruptions of silicic to intermediate composition from one or more magma chambers below the summit. The several major tephra eruptions may be associated with several episodes of caldera collapse, each one involving areas smaller than that of the present caldera. Evidence for sequential collapse is also found in the configuration of the caldera walls which, rather than forming a single circular wall, consist of several walls, in places one inside the other, which in aggregate form an ellipse with an east-west axis. The oldest voluminous ash-flow tuff has a K-Ar age of 510,000 years, indicating a similar age for the earliest caldera. The youngest voluminous tephra unit has not yielded meaningful K-Ar dates, so the age of the most recent collapse is not known. This tephra deposit, however, is deeply eroded and may be many tens of thousands of years old.

The walls of the caldera are mostly covered by younger deposits (talus, pumice falls, etc.), and the wall rocks are only locally exposed. The caldera walls were described in detail by Williams (1935) and Higgins (1973) and consist mostly of platy rhyolite at the base overlain by basaltic-andesite flows, palagonite tuff, cinders, and agglutinated spatter deposits. In a few places the walls also contain welded tuff, pumice falls, obsidian flows, and domes.

The caldera floor (Figure 4) is formed mainly of rhyolitic rocks (domes, flows, ash flows, pumice falls, and explosion breccias). The few mafic rocks that occur in the caldera are older than Mazama ash, except for those along the East Lake fissure which cuts the north caldera wall and which may extend onto the floor beneath East Lake. The fissure has not been dated, but the summit basaltic-andesite flows on the same fissure 2 km to the north were determined to be about 6,090 years old by carbon-14 dating and almost certainly are the same age as the East Lake fissure. Rhyolitic rocks of pre-Mazama age include two domes along the south shore of Paulina Lake, a large obsidian flow in the northeast corner of the caldera, an obsidian dome and an associated buried obsidian flow that extends from the caldera wall northward to East Lake, and a poorly exposed dome(?) south of the central pumice cone. In addition, rhyolitic pumice falls and lacustrine, fluviatile, and landslide deposits locally underlie Mazama ash.

Rhyolitic deposits of post-Mazama age blanket the eastern two-thirds of the caldera (Figure 4). These deposits include obsidian flows, pumice rings and cones, ash flows, pumice falls, and other pumiceous tephra deposits. Isotopic (carbon-14) and hydration-rind dates indicate that they range in age from about 6,700 years to 1,350 years (Friedman, 1977).

The youngest period of volcanism within the caldera was associated with the vent for the Big Obsidian Flow (Figure 5). Initial eruptions produced a widespread pumice fall that covers the southern part of the caldera and eastern flank of the volcano (Sherrod and MacLeod, 1979). Isotopic ages of 1,720±60 (Higgins, 1969) and 1,550±120 years (S.W. Robinson, written communication, 1978) were obtained on carbon collected beneath the fall. The axis of the fall trends N. 80° E. away from the vent for the Big Obsidian Flow; at 9 km from the vent the fall is 4 m thick and at 60 km about 25 cm thick. The pumice fall was followed by eruptions that produced an ash flow that extends over a broad area between the Big Obsidian Flow and Paulina Lake. Three carbon-14 ages cluster at about 1,350 years, suggesting that about 200 years may have elapsed between the pumice fall and ash flow. The final event was the eruption of the Big Obsidian Flow which extends from the south caldera wall 2½ km northward toward Paulina Lake. The pumice fall, ash flow, and obsidian flow are indistinguishable in their trace- and major-element composition, and all are essentially aphyric.

The young rhyolites in the caldera and a few young, but possibly pre-Mazama, rhyolite protrusions on the upper southeast flank differ in chemical composition from older caldera rhyolites and from most older domes and flows on the flanks. Particularly obvious are marked differences in some trace elements such as rubidium (Rb) and strontium (Sr), but the silica content of the young rhyolites also is slightly higher (Figure 6). All of these young rhyolites may be derived from the same magma chamber inasmuch as they are chemically closely similar and all are aphyric or nearly so. If so, parts of the chamber must have been at or above the liquidus as recently as 1,350 years ago and thus are probably still hot.

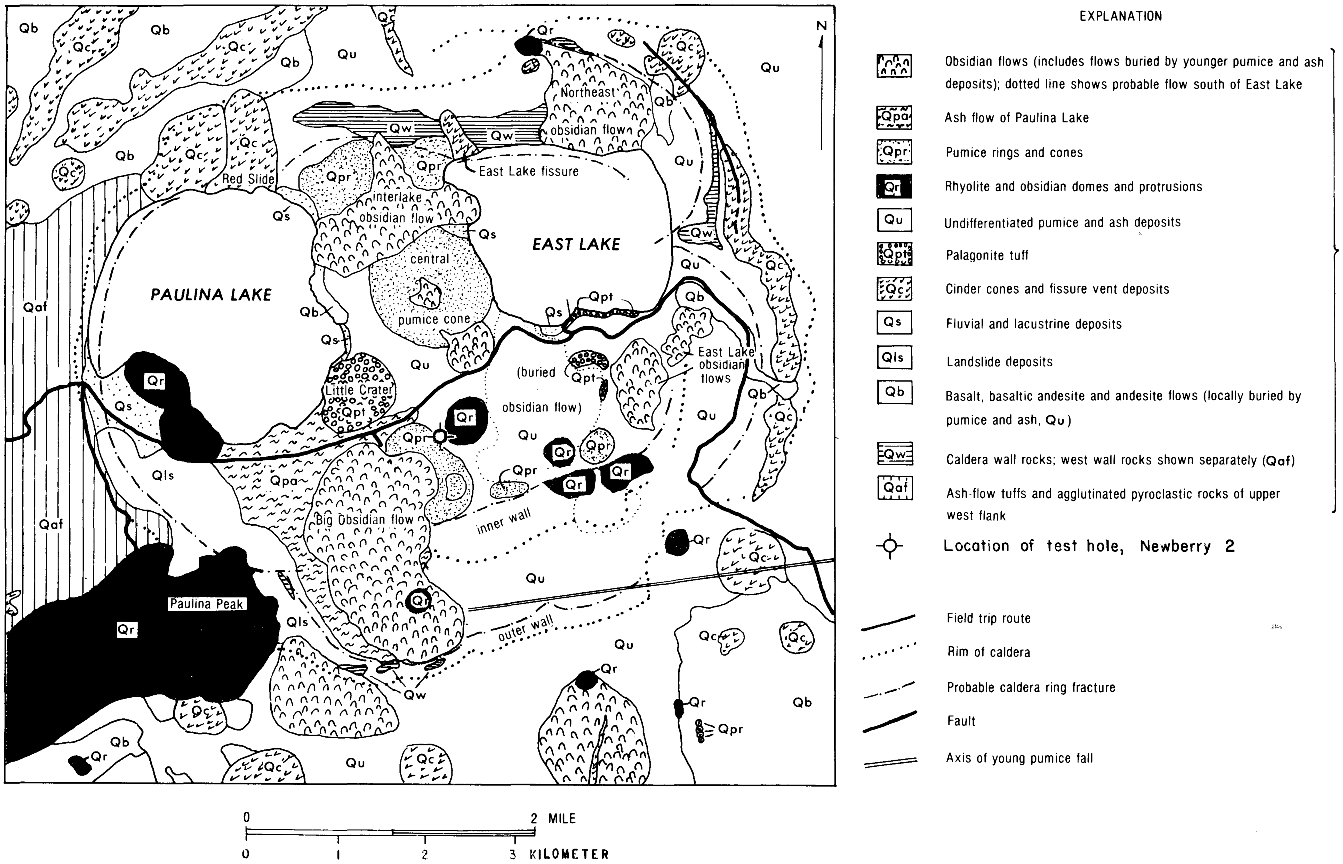

Figure 4. Geologic map of Newberry caldera. Modified from MacLeod and others (1981).

RESULTS OF DRILLING

General

Two exploratory holes were drilled on Newberry Volcano as part of the geothermal and volcanologic studies. Both were drilled by wireline methods so as to provide continuous cores of the rocks that constitute the volcano. The first hole, Newberry 1, was completed in September 1977 on the upper northeast flank of the volcano (Figure 3) to a depth of 386 m. Core recovery was excellent in massive rocks but poor in unconsolidated deposits. The second hole, Newberry 2, was drilled in the central part of the caldera near the locus of vents for rhyolitic rocks that are younger than 6,900 carbon-14 years (Figure 4). The caldera is a scenic recreation area with few roads; consequently, selection of the drill site was dictated partly by environmental and access considerations. In 1978, the first 312 m of the hole was drilled by the mud-rotary method in order to allow for maximum reductions in diameter during later core drilling. During the summers of 1979 and 1981, as funds became available, the hole was deepened by wireline core drilling to a final depth of 932 m in September 1981. In addition, an offset hole was drilled to provide core in parts of the upper section previously drilled by rotary drill. Core recovery ranged from as little as 40 percent in parts of the upper 300 m to more than 90 percent in most of the lower 600 m; only drill cuttings are available for the upper 98 m.

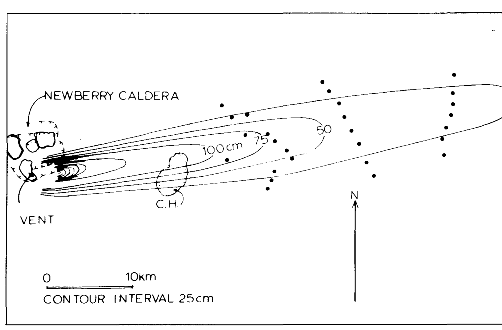

Figure 5. Isopach map of pumice fall from vent at Big Obsidian Flow. China Hat (C.H.) *lies at east base of Newberry Volcano.*

Lithology

Newberry 1 penetrated flows of basaltic to rhyolitic composition with interbedded cinders, breccia, volcaniclastic sand and gravel, pumice-fall deposits, and ash-flow tuff. The total thickness of tephra deposits and volcanic sediments at this site was unexpectedly large, comprising about 55 percent of the section. Flows are generally thin, with a median thickness of about 6 m. Only two flows exceeded 10 m in thickness: a 70-m-thick dacite flow encountered at a depth of 183 m and a 43-m-thick basaltic-andesite flow encountered at 337 m. Analyzed flows include basalt, basaltic andesite, andesite, dacite, and rhyodacite; no one rock type predominates, and the section is not bimodal (basalt-rhyolite) as is generally the case for surface rocks at Newberry.

Small amounts of perched water were found in Newberry 1, notably at 154 and 280 m, but the rocks appeared to be generally unsaturated. Drilling fluids were lost into the formations during most of the drilling.

Newberry 2, in the caldera, penetrated dominantly fragmental rocks to a depth of 500 m and flows and associated breccia below that depth (Figure 7). From 98 to 320 m the rocks are basaltic in composition; from 320 to 746 m they

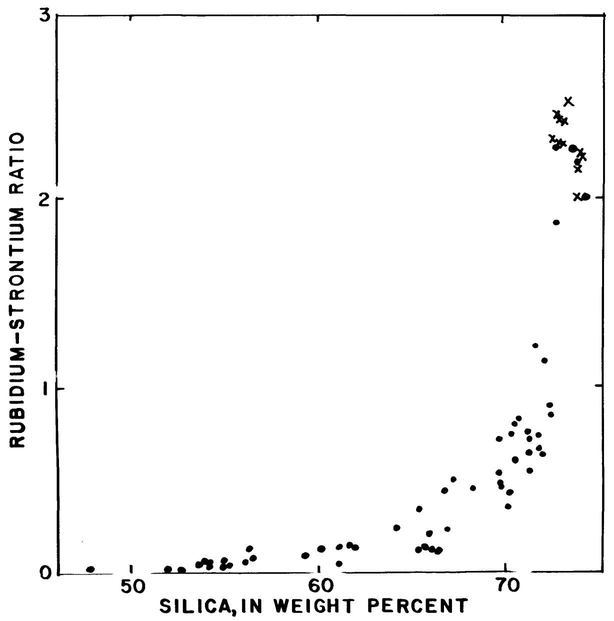

Figure 6. Relation of Rb-Sr ratio to SiO_2 for Newberry rocks. X = *young rhyolites.*

grade downward from rhyolitic to andesitic composition; below 758 m the section consists of basalt or basaltic andesite.

The basaltic tuff, tuff-breccia, and interbedded basaltic sand and gravel that occur between 98 and 290 m are dominantly formed of glassy fragments, suggesting that they may be of subaqueous origin. The underlying sediment in the interval from 301 to 320 m is lacustrine in origin. It consists of thin-bedded to finely laminated claystone to fine sandstone and shows graded bedding, flame structures, and zones of penecontemporaneous deformation. The fine grains that constitute the deposit are mostly hydrated basaltic glass; where cemented locally by carbonate, the glass is fresh. Well-bedded pumiceous ashy sand and gravel of either lacustrine or fluviatile origin occur between 320 and 360 m. They differ from sediments above in that they are coarser grained and dominantly formed of fragments with rhyolitic composition.

Pumice lapilli tuff occurs between 360 and 500 m. It consists of numerous units 3 to 12 m thick, is poorly sorted, and contains interbedded lithic breccia with ashy matrix. Individual units of the tuff range from massive to doubly graded with larger light pumice lapilli at the top and dense lithic fragments at the base. Some lithic breccias appear to grade upward into pumice lapilli tuff, whereas others form discrete units with sharp boundaries. Pumice lapilli show no flattening, but the lapilli tuffs are probably ash-flow tuffs on the basis of their poor sorting and grading. The lithic breccias are probably ash-flow lag breccias and explosion breccias. A rhyolite sill occurs in this section at 460 to 470 m, and a 1½-m-thick unit of perlitic glass (welded tuff?) occurs at 479 m.

Flows form most of the section from 500 m to the bottom of the hole. Most flows are massive or fractured; however, thick units of breccia also occur in the sequence, and most massive flows have brecciated tops and bottoms. The flow sequence appears to be divided into two units separated by a zone of tuffaceous pumiceous sand and silt and ash-flow tuff(?) that occurs between 746 and 758 m. Above these sediments the flows are rhyolitic to dacitic and andesitic in composition, whereas below that depth they are basaltic andesite and basalt.

Alteration in the core is highly variable but generally more intense lower in the hole. Fragmental rocks that initially were glassy are locally altered to clay minerals. Massive rocks commonly contain sulfides (marcasite, pyrrhotite, and pyrite), carbonates (calcite and siderite), and quartz along fractures. Many breccias in the lower part of the hole have a bleached appearance and are altered to clay minerals, quartz, carbonates, epidote, chlorite, and sulfides.

Some preliminary inferences and conclusions can be made, based on lithology of the cores, even though they have not yet been studied in detail. First, the lacustrine sediments that occur at a depth of about 300 m indicate that the caldera was once much deeper and may have been physiographically similar to the Crater Lake caldera. These sediments lie about 790 m below the present highest point on the caldera rim, a depth comparable to that from the rim above Crater Lake to its base. The fragmental rocks of sedimentary and pyroclastic origin that form the upper 300 m of the core appear to represent a discontinuous filling of a once much deeper caldera. Second, the 130 m of pumice lapilli tuff and associated breccia that occur below the lake sediments are probably ash flows and may relate to one or more periods of collapse of the caldera. It is not obvious from preliminary studies that these tuffs correlate with ash flows on the flanks; they are most like the oldest rhyolitic ash-flow tuff, but unlike it in that they are not welded. Third, the flows in the lower part of the hole are

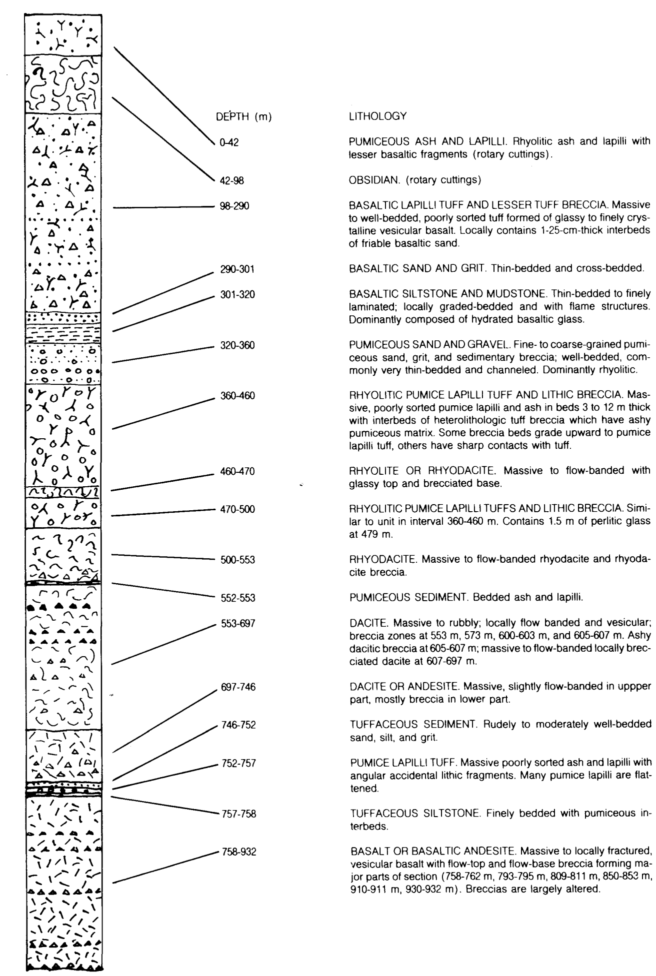

Figure 7. Preliminary generalized lithologic log of Newberry 2. Rock names are based on visual examinations and have not been confirmed by chemical analyses.

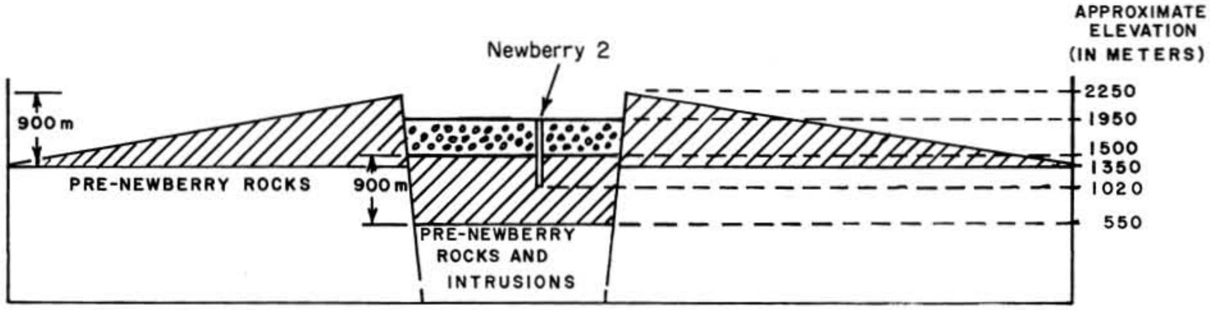

Figure 8. Schematic cross section of Newberry Volcano showing probable position of collapsed block.

similar to flows on the flanks of the volcano and may be the former upper part of the volcano that collapsed to form the caldera.

We do not know the shape of the old surface upon which Newberry Volcano is built or the original shape of the volcano before collapse. Thus, we can only crudely estimate the amount of collapse and the possible elevation of the base of the collapse block. The difference in elevation between the lowest flank flows and the caldera rim is about 900 m, and this difference may approximate the thickness of volcanic rock adjacent to the caldera. As the former summit was undoubtedly at a higher elevation than the present rim, this figure represents a minimum thickness of the collapse block. If the top of the section of flow rocks in the hole at an elevation of about 1,500 m represents the top of the collapsed block, then

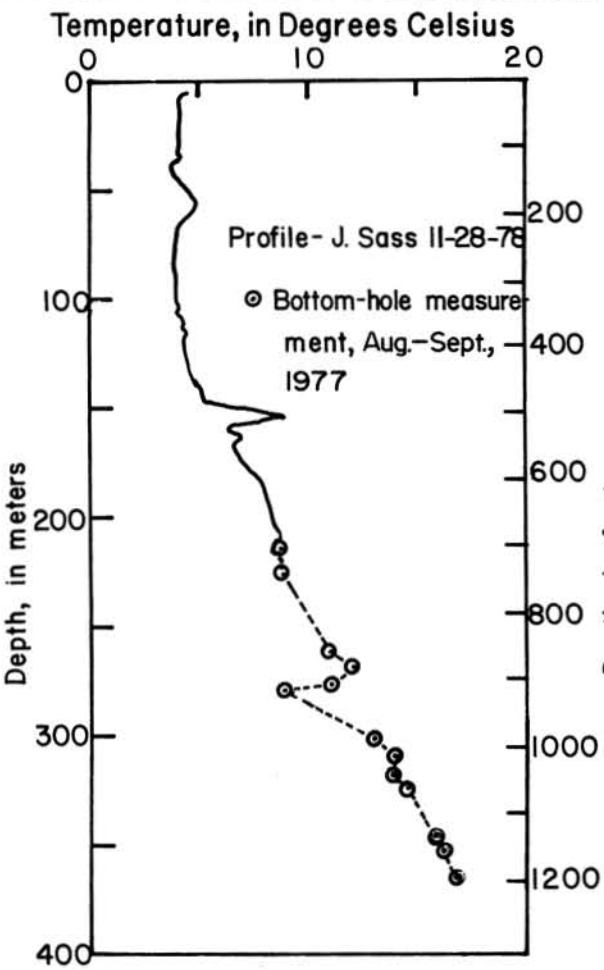

Figure 9. Temperatures measured in Newberry 1.

its base lies at about 550-m elevation. Thus the base of Newberry rocks in the caldera is roughly 800 m or more lower than the base of the volcano outside the caldera and is 500 m or more below the bottom of the hole. These crude estimates are shown diagrammatically in Figure 8, in which a single rather than multiple-collapse block is illustrated.

Temperature and heat flow

The temperature profile obtained in Newberry 1 (Figure 9) on the flank of the volcano indicates that heat flow is suppressed in the upper 90 m of rock, presumably by the vertical flow of cool water in the permeable sediments that predominate in this zone. Below 90 m, the thermal regime is predominately conductive, although perturbations in the profile indicate minor flows of both cooler and warmer water. For example, the peak in the profile at 155 m is probably due to the flow of warm water in a permeable zone at the scoriaceous base of a dacitic flow and the rubbly top of an andesitic flow; in the interval 270-280 m, ground-water flow of differing temperatures may occur in beds of cinders, grit, and scoria that overlie the rubbly top of an andesitic flow.

The smoothed thermal gradient in the lower 260 m of the hole is approximately 50° C/km, which is significantly lower than the mean gradient of 65° C/km estimated for the region (Blackwell and others, 1978). On the basis of measured values in rocks at Newberry 2, the mean thermal conductivity in the lower 260 m of Newberry 1 is estimated to be less than 1.3 $W°C^{-1}m^{-1}$. The conductive heat flux is estimated to be no greater than about 60 mW/m^2, or a little more than one-half the expected value for the High Cascade region (Blackwell and others, 1978; Couch and others, 1981). In the light of the high heat flux discovered later beneath the caldera, the low values found in Newberry 1 are believed to result from flow of cool water at depths below 386 m (the base of the hole) which depresses the thermal gradient and transfers heat radially away from the caldera.

Representative profiles and bottom-hole measurements obtained in Newberry 2 (Figure 10) show a quasi-linear conductive gradient in the lower 230 m of the hole and large convective anomalies in the upper 700 m. Repeated logging in the hole as drilling progressed demonstrated that, over periods of time on the order of a year, the profiles represent stable thermal regimes in the rocks at the drill site. It seems probable, however, that over longer periods of time the temperatures and heat flows would be observed to be in a transient state.

The major displacements in the temperature profile generally coincide with higher than average permeabilities in the core samples and flows of formation water observed in the borehole. For example, the temperature minimum at 280-m to 290-m depths is probably due to the flow of cool water observed in a cavernous zone within beds of basaltic sand and grit. A temperature maximum at depths between 350 m and 450 m is associated with permeable sand, gravel, and lithic

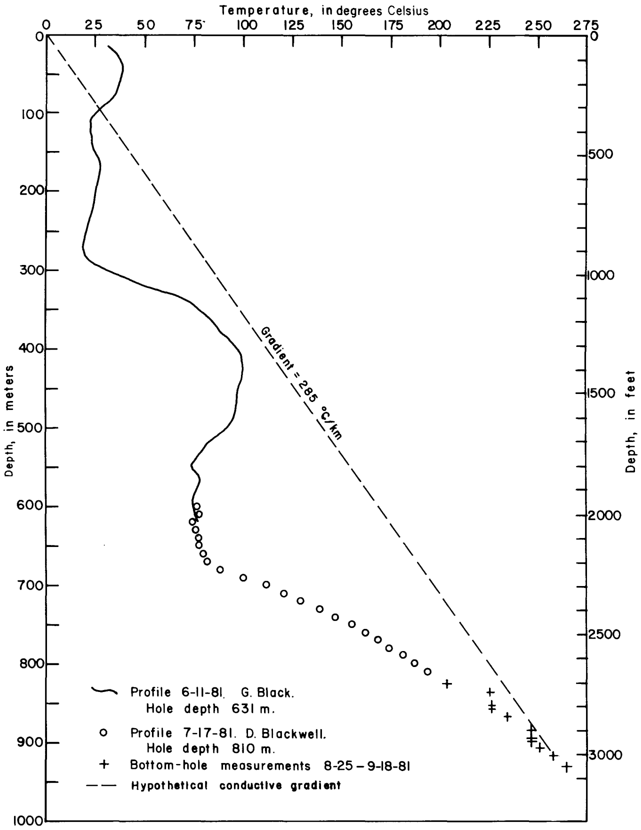

Figure 10. Temperatures measured in Newberry 2 and hypothetical conductive gradient projected from bottom of hole to land surface.

breccias in which flows of warmer water diluted the drilling mud. A significant water flow in brecciated dacite encountered between 555 m and 564 m probably accounts for much of the temperature minimum observed between 550 m and 610 m. The stronger flows produced up to one-half liter per second in the well bore, and many weaker flows probably went undetected. Mud circulation was completely lost in strata of rhyodacite, pumiceous sediment, and dacite in the interval from 515 to 610 m.

Below 758 m, permeable zones were few, and although gas was encountered in many hydrothermally altered strata, there was no evidence of water or steam. Fluid recovered from the bottom 2 m of the hole during a 20-hour flow test (Sammel, 1981) is now believed likely to have consisted largely of drilling fluids injected into the formation combined with dry gas already present in the formation.

Available evidence indicates, therefore, that vertical permeabilities are generally low in the caldera fill as well as in the collapsed caldera block. The vertical flow of both geothermal fluids and meteoric recharge water is probably restricted to faults, ring fractures, or brecciated intrusion conduits. Lateral flow may be confined to those permeable strata that have good hydraulic connections with water-bearing vertical fracture zones.

Surface expression of discharge from the hydrothermal system occurs at only three places in the caldera and is entirely absent on the flanks, so far as is known. Small springs of moderate temperature rise along the northeast margin of Paulina Lake and the southwest margin of East Lake. Several fumaroles occur along the northeast margin of the Big Obsidian Flow. The total heat flux from these sources is unknown but is thought to be small.

The vertical component of the heat flux in the lower 180 m of Newberry 2 can be estimated on the basis of the more reliable temperatures by calculating the mean thermal gradient (approximately 600° C/km) and estimating the mean thermal conductivity from four measured values (about 1.9 $W°C^{-1}m^{-1}$). The conductive heat flux calculated from these estimates is 1.1 W/m^2, which is more than 10 times the regional average. This large heat flux reflects in part the rate of convective heat transfer in the interval from 550 to 670 m. If heat were not being removed in this zone, temperatures in the rocks above the linear profile would presumably be higher than those observed, and both the gradient and the heat flux would be lower than those now observed.

Convective effects above a depth of 700 m cause the total heat flux at the drill site to be greater than the 1.1 W/m^2 calculated for the lower 170 m. Fluid flowing laterally in the intervals from 550 to 670 m and 100 to 280 m absorbs heat from warmer zones above and below and presumably transports this heat away from the site. Using linear approximations of temperature gradients above and below these intervals and estimating corresponding thermal conductivities, we obtained an estimate of 2.5 W/m^2 for the total heat flux into these intervals. Assuming a conductive heat flux in the top 20 m of dry caldera fill and a land-surface temperature equal to the mean annual air temperature of 0° C in the caldera, we estimate an additional flux of 0.5 W/m^2 conducted to the land surface. Thus, the total lateral and vertical heat flux at the drill site above a depth of 930 m may be at least 3 W/m^2.

This heat flux is considerably larger than the conductive flux of 0.3 W/m^2 that hypothetically would exist on the basis of a linear temperature gradient (285° C/km) between the measured temperature at the bottom of the hole and a land-surface temperature of 0° C (Figure 10) and a harmonic mean thermal conductivity for the entire section, based on 47 measured values, of 1.1 $W°C^{-1}m^{-1}$. This hypothetical conductive heat flux is itself anomalously large, possibly because of convective effects occurring below the bottom of the drill hole.

The high rate of heat flow in the vicinity of the drill site may not be typical of heat flow over the entire 30 km^2 of the caldera floor. Flows of cooler water, apparently interstratified with flows of warmer water, produce the anomalies in the temperature profile that have been described above. These anomalies suggest that lateral flows of water beneath the caldera floor have separate origins and complex flow paths. It is likely, therefore, that the distribution of thermal discharge in the caldera is highly variable, both spatially and temporally, in response to varying conditions in the hydrologic regime.

SOURCE OF GEOTHERMAL HEAT

The highest observed temperature (265° C), large heat flux, and recency of volcanism at Newberry strongly suggest that the heat source is of magmatic origin. The widespread occurrence of rhyolitic rocks of similar compositions that have been erupted during at least the last 7,000 years and as recently as 1,350 years ago suggests that the magma chamber may be several kilometers wide and that temperatures could still be partly in the magmatic range.

Geophysical studies by USGS workers and others have elucidated some of the large-scale characteristics of the crustal rocks beneath Newberry, but the studies do not conclusively indicate either the presence or absence of shallow crustal magma chambers. From their reduction of gravity data obtained by Andrew Griscom, Williams and Finn (1981) inferred the existence of a large, dense stock at a depth less than 2 km beneath the volcano. Although there are differing views among the geophysicists regarding the size and shape of the subvolcanic stock, there is general agreement that a stock exists. This interpretation is supported by teleseismic data that suggest that there is a large compressional-wave velocity contrast in the area, with higher velocities localized under the caldera (Mahadeva Iyer, oral communication, 1981). The teleseismic data fail to show evidence for a molten mass; the limit of lateral resolution for the data, however, may be about 3 km. Magnetotelluric soundings at Newberry (Stanley, 1981) are inconclusive but suggest that a body having low to intermediate resistivity may occur at a depth of about 1½ km.

Heat-flow data derived from the measurements at Newberry 2 do not provide a firm basis for limiting the size, depth, or temperature of a magmatic heat source. Preliminary analysis of the data suggests, however, that if the total heat flux estimated in Newberry 2 represents a widespread and long-lasting thermal regime beneath the caldera, a magmatic source would be likely to have a diameter of several kilometers and to have been continuously supplied with magma for a period of thousands of years prior to the most recent eruption. If the apparent heat flux at Newberry 2 represents only a local anomaly within the caldera, the source of heat could be significantly smaller.

The results of such analyses are sensitive to assumptions regarding the transient state of the temperature profile in Newberry 2 and the applicability of the estimated heat flux to other parts of the caldera. Calculations based on several conceptual models show, for example, that if the heat flux estimated in Newberry 2 represents the flux over the caldera during the 1,350 years since the last eruption and if there has been no new input, much of the magma in a 3-km-wide chamber could have solidified and the temperatures could have decreased below the solidus temperature.

A possible limiting case for temperatures below the drill hole can be derived on the basis of the assumption that heat flow in the basaltic-andesite flow rocks of the collapse block is predominately conductive. The following specific assumptions are used: (1) the nearly linear gradient observed between 860 and 930 m (505° C/km) represents a conductive regime in the basaltic and basaltic-andesite rocks near the base of the volcano; (2) this gradient continues in rocks of low vertical permeability to the base of the collapsed caldera block at a depth of 1.4 km beneath the caldera floor (Figure 8). The temperatures at the base under these conditions would be about 500° C. Below the base, possible effects of intrusive activity in the pre-Newberry rocks make the presence of hydrothermal convection seem more probable, and continued extrapolation of the temperature gradient is not justified.

CONCLUSIONS AND REGIONAL IMPLICATIONS

Evidence of a high potential for the development of geothermal energy at Newberry is compelling, but the nature and magnitude of the resource currently is poorly defined. The flow test conducted in Newberry 2 suggests that if a hot hydrothermal reservoir exists at Newberry, it is tightly confined by overlying rocks of low thermal and hydraulic conductivity. The paucity and small size of geothermal emanations in the caldera also attest to the probable low vertical permeability of the caldera rocks. Many strata in the upper 670 m of the hole appear to have moderately high permeabilities, but the stratification of the warm and cool zones in the rocks demonstrates that the horizontal permeability greatly exceeds the vertical at the drill site.

Because the more permeable rocks in the lower part of the hole are the brecciated tops and bottoms of flows, it is reasonable to suppose that similar breccia zones may occur at greater depths. Marked changes in permeability and porosity may occur below the base of the collapsed caldera block in pre-Newberry rocks that are fractured and faulted by magmatic intrusion. If late intrusions of magma have not penetrated the collapsed block, the largest reservoir of high-temperature fluids seems most likely to occur below the block in the pre-Newberry rocks. Careful testing by additional and probably deeper drill holes will be required in order to evaluate these possibilities and the magnitude of the geothermal resource at Newberry.

Geological and geophysical studies at Newberry have shown that this large composite volcano differs significantly from most other volcanoes in the Cascade Range. Unlike most of the well-known stratovolcanoes, but in common with Mount Mazama in Oregon and Medicine Lake Volcano in California, Newberry has a summit caldera and has experienced large eruptions from silicic magma chambers. Large volumes of mafic magma probably have resided for long periods of time in the crust at these three locations in order to have produced the voluminous silicic magmas (Hildreth, 1981; Bacon, 1981). Newberry appears to be unique, however, in its position at the end of a 10-million-year progression of silicic volcanism across the northern edge of the Basin and Range Province. There is at present no evidence that the progression continues into the High Cascades, where a possible extension might culminate in the vicinity of the Three Sisters.

The geological parallels between Newberry Volcano in Oregon and Medicine Lake Volcano in California permit some inferences concerning the geothermal potential at the latter site. The geology of the Medicine Lake area is currently being studied by Julie Donnelly-Nolan under the USGS Geothermal Research Program, and a number of geophysical studies have been made in the area (see Hill and others, 1981; Williams and Finn, 1981; Christopherson and Hoover, 1981; and Stanley, 1981). The results of these studies show that although surface indications of geothermal activity are sparse, large volumes of silicic rocks have been erupted at Medicine Lake during the last several thousand years and the caldera is underlain at shallow depths by dense rocks of high seismic velocity and low to moderate resistivity. The results of the Newberry drilling thus present an encouraging indication of the potential for geothermal resources at Medicine Lake.

Certain implications of the results at Newberry may have a wider regional significance. The probable existence of a magmatic heat source at Newberry suggests that other magmatic heat sources of significant magnitude may exist at fairly shallow depths within the Cascade region. Geothermal anomalies associated with these heat sources are likely to be masked by rocks of low vertical permeability and by the lateral flow of ground water in the same way that the anomaly is hidden at Newberry. Recharge to deep hydrothermal systems may be impeded by low vertical permeabilities as at Newberry, and the amounts of recharge may be significantly less than would be expected on the basis of local precipitation rates. On the other hand, deep regional ground-water flow systems may occur in older rocks beneath the Quaternary volcanics; where these rocks are fractured and faulted, as they may be in the vicinity of subvolcanic intrusions, permeable geothermal reservoirs may occur.

Crucial questions for exploration in the Cascade region are whether or not surface geophysical methods and shallow test drilling will be able to delineate areas underlain by shallow magma chambers or hot intrusive rocks and whether or not strata having moderately high permeability and significant lateral extent occur in the vicinity of such heat sources.

The numerous thermal springs that rise in the Cascade region may be of little help in locating magmatic sources because, with few exceptions, the springs are not closely related to the major Quaternary volcanic centers. Some of these springs may be the surface expression of lateral flow that originates in geothermal reservoirs at some distance from the surface outlet. Others may be the result of local deep circulation in faults and fracture zones at the boundary between rocks of the High Cascades and the older rocks of the Western Cascades. In either case, they may not reliably indicate the location of geothermal reservoirs associated with young intrusive rocks.

The development of geothermal energy in the Cascades will probably depend on the exploitation of hydrothermal convection systems that concentrate the heat from deeper sources and transport it to shallow depths where the energy can be economically extracted. Hydrothermal systems that function in this way also tend to accelerate the decay of temperatures in the heat sources and shorten the useful lives of the systems. Nevertheless, the positive indicators of geothermal potential in the Cascade region, high heat flows and shallow silicic intrusive rocks, encourage the belief that economical sources of geothermal energy may be found in the region. Deep drilling will probably be required in order to determine favorable locations and to ascertain the extent and nature of the geothermal reservoirs.

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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.

SEDIMENTOLOGY AND TECTONICS OF UPPER CRETACEOUS ROCKS, SOUTHWEST OREGON, by Joanne Bourgeois (Ph.D., University of Wisconsin-Madison, 1980)

Southwest Oregon is a region of complex tectonostratigraphic terranes. Three Upper Cretaceous (Campanian-?Maestrichtian) formations occur there in fault-bounded slivers, in fault and depositional contact with the Upper Jurassic Otter Point Complex, a volcanic-arc assemblage. These four units occur only west of high-angle, NNW-trending faults, making up a terrane unlike anything to the east. Sedimentation patterns and tectonostratigraphic relationships of the Upper Cretaceous formations indicate that they were deposited in a tectonically active setting where vertical faulting played a significant role. In addition, clast compositions of conglomerates suggest the Klamath Mountains are an unlikely source terrane—apparently these Upper Cretaceous rocks are no longer near their source. I tentatively postulate that they were deposited in a borderland-type basin, with southern California as their sediment source, and that they were then transported north during latest Cretaceous to early Eocene time and accreted to the Oregon coast.

The oldest Upper Cretaceous rocks in southwest Oregon are the (tentatively named) Houstenaden Creek Formation (500+ m thick) and an apparently correlative sequence at Blacklock Point (400+ m thick). As is typical of Pacific Coast of North America stratigraphy, the Houstenaden and Blacklock sequences are geographically limited but provide good examples of the influence of tectonics on sedimentation. They are both thickening- and coarsening-upward sequences consisting principally of amalgamated turbiditic sandstones. Lithologic, sequential, and structural similarities support the proposal that the two sequences are equivalent, as suggested by fossil data. They could either represent two different lobes on a single submarine fan or be separate fans. I postulate that they record rapid suprafan-lobe progradation during the Late Cretaceous and that they were probably deposited in a strike-slip, rifted-margin setting, with a mixed magmatic-arc/uplifted-basement source terrane.

The Cape Sebastian Sandstone (Campanian) was deposited unconformably on Houstenaden Creek Formation and also on Otter Point Complex. It is a 200-m thick, fining-upward, transgressive sequence representing foreshore to offshore deposition; progressively increasing depth of deposition is indicated by both physical and biogenic sedimentary structures. Basal Cape Sebastian conglomerate is overlain by trough-cross-bedded and plane-laminated coarse sandstones. Most of the formation comprises hummocky-bedded and burrowed sandstone. The uppermost part consists of alternating laminated, very fine sandstone and progressively thicker, burrowed sandy siltstone. These sedimentary structures have been observed on modern continental shelves and also in progradational ("regressive") sequences in the Cretaceous of the Western Interior, where thick transgressive sequences are rare. Cape Sebastian deposition reflects rapid shelf sedimentation during sea-level rise.

The Hunters Cove Formation is a 300-m-thick, fining-upward sequence, conformably overlying Cape Sebastian Sandstone. Overall, the formation is fine-grained (sand:shale <1:3) and consists of T(a)bc(de) turbidites and silts and shales. The presence of slump deposits, channelized sandstones within fine-grained sequences, and irregular, coarse-grained layers suggests that the formation was deposited on a submarine slope or base of slope. The formation contains thick sandstones that exhibit varied sedimentary structure indicating rapid deposition, soft-sediment deformation, and fluid-escape processes. These sands were probably deposited at a break in slope where sedimentation was rapid. The formation also contains a thick slump and slump-breccia zone containing clasts of basal Cape Sebastian Sandstone, indicating that vertical faulting was contemporaneous with Hunters Cove deposition. The Hunters Cove Formation probably represents submarine-slope sedimentation in a fault-influenced basin concomitant with sea-level rise. It is part of a small but complex package of Upper Cretaceous rocks in southwest Oregon that illustrates many effects of tectonics and sea-level change on sedimentation.

GEOLOGY AND PETROLOGY OF THE YAMSAY MOUNTAIN COMPLEX, SOUTH-CENTRAL OREGON: A STUDY OF BIMODAL VOLCANISM, by Carl William Hering (Ph.D., University of Oregon, 1981)

The southern and central Cascades are bounded to the east by the Basin and Range province. Along this boundary a number of large shield complexes, noted for their bimodal associations, are located. I have examined the geology and petrology of a Pliocene center lying along this axis, the Yamsay Mountain complex of south-central Oregon. A thorough understanding of the bimodal association here furthers our knowledge of the volcanic and tectonic evolution of central Oregon. The Yamsay Mountain complex is a large shield approximately 27 km in diameter, rising over 700 m above the surrounding basalt plateau. A caldera at the summit of the shield, associated with venting of the Silver Creek Welded Tuff, has been filled by younger basaltic andesites and dacites. Several cycles of mafic and silicic volcanism are indicated, and the volume of silicic rocks increases with time.

Major-element analyses demonstrate the calc-alkaline character and bimodal distribution of lavas in the area. Detailed trace-element analyses facilitate evaluation of petrologic models concerning the origin of the bimodal association. Inter- and intra-vent compositional variations in the basaltic andesites suggest that they are related primarily by discrete partial melting events and have not undergone the extensive fractionation necessary to produce the silicic lavas. Modeling indicates that these rocks are formed by differentiation of dacitic parental magma. Crystallization along the walls of a chamber allows fractionated liquid to rise and separate from the crystal residuum, giving rise to compositional zonation within the chamber. Rhyolitic obsidians are an extreme example of this fractionation process, having large Eu anomalies and low Sr contents although being devoid of plagioclase phenocrysts. It is concluded that the parental magmas for the silicic rocks are formed by melting of crustal rocks of basaltic composition. Intense mafic volcanism and extensional tectonics facilitate melting, leading to the development of a bimodal association. This relationship explains mafic and silicic cycles of activity and the increasing volume of silicic rocks with time. Northwestward extension of Basin and Range structures may be responsible for late-stage divergent activity in the Cascades. □

Brightly colored digital map shows U.S. elevations at a glance

A brightly colored map, created from digital data and showing elevations in the United States at a glance, has just been published by the U.S. Geological Survey (USGS).

The experimental digital terrain map of the United States uses 32 color shades, ranging from dark blue at sea level to bright red at the highest elevations, to depict the topography of the 48 states. Scanning the new USGS map, persons unfamiliar with topographic maps may readily see that mountainous areas are those colored in red; valleys and low-lying areas appear in blue, in-between areas in shades of yellow and green.

A metric altitude graph relates 32 color shadings with elevation differences and uses a different shading for each 100-m (328-ft) rise in elevation in all areas below 3,000 m in elevation. The darkest blue depicts areas from sea level to 100 m, while bright red denotes areas that are 3,500 m (approximately 11,500 ft) or more above sea level.

The experimental map represents the application of some of the newest technology in digital mapping, a process in which computerized information about the Earth's surface is transferred to maps by means of electro-mechanical or computer-driven plotters. To produce the new map, elevation data from 1:250,000-scale maps of the United States were converted to a rectangular grid, with each tiny grid square on the map representing 6 km^2 (2.3 square miles) on the ground.

No specific river courses are shown on the map, but some major rivers can be traced by following the fine green lines and trails of progressively deeper shades of greens and blues that distinguish lower elevations of river beds from the surrounding terrain as the rivers flow seaward.

Cultural features (cities and roads) also are not shown on the map, but state boundaries are clearly outlined in black. As for color variation, in relation to elevation differences, Florida and Delaware are the only two states that are entirely dark blue (less than 100 m above sea level). At first glance Louisiana appears to be all dark blue, but closer examination reveals a few tiny patches of the next lighter shade of blue, indicating areas with elevations between 100 and 200 m.

California, Washington, Oregon, and Arizona are the only states that include the full range of colors, from dark blue through the lighter blues to greens, yellows and red. Colorado, with the nation's greatest concentration of high mountains, has more red areas than any other state. White spaces on the map represent below-sea-level areas of the Salton Sea and Death Valley in California.

In addition to being a colorful, easily interpreted relief map for the general public, the new digital terrain map can be used by scientists to interpret linear and curvilinear broad-scale tectonic deformations in the earth's crust, especially those that have occurred in the recent past.

The new digital terrain map of the United States was generated from a USGS digital data base created from data obtained from the National Geodetic Survey (NGS). NGS received the data from the Department of Defense Electromagnetic Compatibility Analysis Center (ECAC), whose primary data source was the Defense Mapping Agency. Data for a few degree squares, especially around the coastline, were obtained by the ECAC from other sources.

The author of the map is Richard H. Godson, a USGS geophysicist in Denver, Colo. The map, *Digital Terrain Map of the United States*, was published as USGS Map I-1318 and can be purchased for $2.50 per copy from the Western Distribution Branch, U.S. Geological Survey, P.O. Box 25286, Federal Center, Denver, CO 80225; or the Eastern Distribution Branch, U.S. Geological Survey, 1200 South Eads St., Arlington, VA 22202. Orders must include the map number, I-1318, and checks or money orders payable to the U.S. Geological Survey. □

Diamond Craters Outstanding Natural Area dedicated

Diamond Craters, located 55 mi southeast of Burns in Harney County, southeastern Oregon, was dedicated as an Outstanding Natural Area (ONA) by the Bureau of Land Management (BLM) on September 18, 1982. The area has been described by geologists as having the best and most diverse basaltic volcanic features in the United States and all within a comparatively small and accessible place.

Joshua Warburton, Manager of the Burns District of the BLM, was Master of Ceremonies at the dedication. Guest speakers were Ellen Benedict (former Diamond Craters Coordinator) of Pacific University (Adjunct Professor of Biology); William G. Leavell, Oregon State Director of the BLM; Dale White, County Commissioner of Harney County; and Chad Bacon, Drewsey-Riley Resource Area Manager of the Burns District of the BLM.

Central vent complex, Diamond Craters.

The ONA designation of the 16,656 ares of public lands within Diamond Craters was published in the Federal Register during the week of April 5, 1982. Diamond Craters is now protected under several complementary designations and actions: (1) Area of Critical Environmental Concern (ACEC) – designated in December 1980 by the joint action of Chris Vosler (then Burns District Manager) and Bill Leavell. The ACEC designation means that Diamond Craters is given a high priority status in management decisions and is managed under an ACEC Plan Element written specifically for the area; (2) Protective withdrawal and designation as the Diamond Craters Geologic Area – signed by Under Secretary of Interior, Guy Martin, in January 1981; and (3) the ONA designation signed by Bill Leavell in April 1982 and approved by Secretary of the Interior James Watt. □

Department releases geological, geothermal, and geophysical data

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the release of the following publications and open-file reports:

Special Paper 14

Special Paper 14, *Geology and Geothermal Resources of the Mount Hood Area, Oregon*, is a comprehensive report of the geology of Mount Hood, with special emphasis on geothermal exploration. The 100-page report shows the results of investigations conducted over the last five years by industry, university, and DOGAMI staff researchers. Its publication was supported primarily by the U.S. Department of Energy and by the State of Oregon.

The contributions by fourteen different authors include a summary of all heat-flow and gradient data, extensive chemical and mineralogical analyses from two deep wells, heat-flow models, and new information on the volcanic stratigraphy and structural geology of the Mount Hood area. Purchase price of Special Paper 14 is $7.

GMS-20

A new map titled *Map Showing Geology and Geothermal Resources of the Southern Half of the Burns 15' Quadrangle, Oregon* is published as map GMS-20 in DOGAMI's Geological Map Series. The area covered by the multicolor map (scale 1:24,000) is the south half of the Burns 15-minute quadrangle in Harney County and extends approximately 10 mi to the west and 6 mi to the south of the city of Burns.

The map shows 22 different surficial and bedrock geologic units, the geologic structure, and a geologic cross section of the area. It also identifies thermal springs and wells and supplies temperature and heat-flow data for them. Cost of GMS-20 is $5.

GMS-26

A set of three one-color offset-printed geophysical maps showing the residual gravity of the Oregon Cascade Range has been released in the Geological Map Series as GMS-26, *Residual Gravity Maps of the Northern, Central, and Southern Cascade Range, Oregon, 121°00' to 122°30' W. by 42°00' to 45°45' N.*

The maps cover the north, center, and southern portions of a strip about 65 mi wide that extends from the northern to the southern borders of the state. The residual-gravity contours are printed on a topographic base at a scale of 1:250,000. These maps also show the locations of gravity stations used for these and previously published gravity maps (GMS-8, -15, and -16).

The mapping project was conducted by researchers of the Oregon State University Geophysics Group and supported by the U.S. Geological Survey and the U.S. Department of Energy. Purchase price of the set is $5.

Open-File Report 0-82-3

Another map, *Geologic Map of the Langlois Quadrangle, Oregon*, has been published as DOGAMI Open-File Report 0-82-3. The Langlois 15-minute quadrangle is located on the southern Oregon coast just east of Cape Blanco and extends from the southern edge of Coos County south to Port Orford. The blackline ozalid map (scale 1:31,250) identifies 22 surficial and bedrock geologic units and shows their structural relationships in the quadrangle.

The map was compiled by former DOGAMI staff member M.E. Brownfield and is based largely on field work performed for graduate degrees at the University of Oregon by Brownfield, R.L. Phillips, and R.L. Lent. Purchase price of Open-File Report 0-82-3 is $5.

Open-File Report 0-82-8

Open-File Report 0-82-8, *Gravity and Aeromagnetic Maps of the Powell Buttes Area, Crook, Deschutes, and Jefferson Counties, Oregon*, covers a wide region around the Bend-Redmond-Prineville triangle in central Oregon. Centered on an area of anomalously high geothermal gradients at Powell Buttes, the maps will aid the geothermal exploration efforts at Powell Buttes and in adjacent areas.

The four blackline ozalid maps, all at a scale of 1:62,500, show the results of studies by the Geophysics Group of Oregon State University and include data from a number of new gravity stations. The individual maps show (1) residual gravity, (2) free-air gravity anomalies, (3) complete Bouguer gravity anomalies, and (4) total-field aeromagnetic anomalies. Cost of the complete set of maps is $8.

Open-File Report 0-82-9

A geophysical study presenting and interpreting gravity data of the Cascade Range with a view toward geothermal and mineral exploration has been released as DOGAMI Open-File Report 0-82-9, *Gravity Anomalies in the Cascade Range in Oregon: Structural and Thermal Implications.* The 66-page report by the Geophysics Group of Oregon State University summarizes gravimetric measurements made in the Cascades and surrounding regions by many investigators since approximately 1965. It contains page-size reproductions of free-air, Bouguer, regional, and residual gravity maps of the Cascade Range, many of which have been published at larger scale in the Department's Geological Map Series. The report also includes crustal and subcrustal cross sections through the northern and southern parts of the Oregon Cascades.

In discussing the structural and geothermal implications of the observed gravity anomalies, the authors develop a model of the Cascades that is characterized by a fracture zone extending along and across the transition zone between the Western and High Cascades north of Crater Lake and continuing south through the Klamath basin and Klamath graben. They conclude that this zone presents likely targets for both geothermal and mineral-resource exploration. Cost of Open-File Report 0-82-9 is $5.

All of these publications and reports may be purchased from the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. Orders under $50 require prepayment. □

GSOC luncheon meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

November 19—*Indonesia*, by Saleem Farooqui, geologist, Shannon and Wilson, Inc.

December 3—*Adventures in the Himalayas*, by Lute Jerstad, President, Lute Jerstad Adventures.

For additional information, contact Viola L. Oberson, Luncheon Program Chairwoman, phone (503) 282-3685. □

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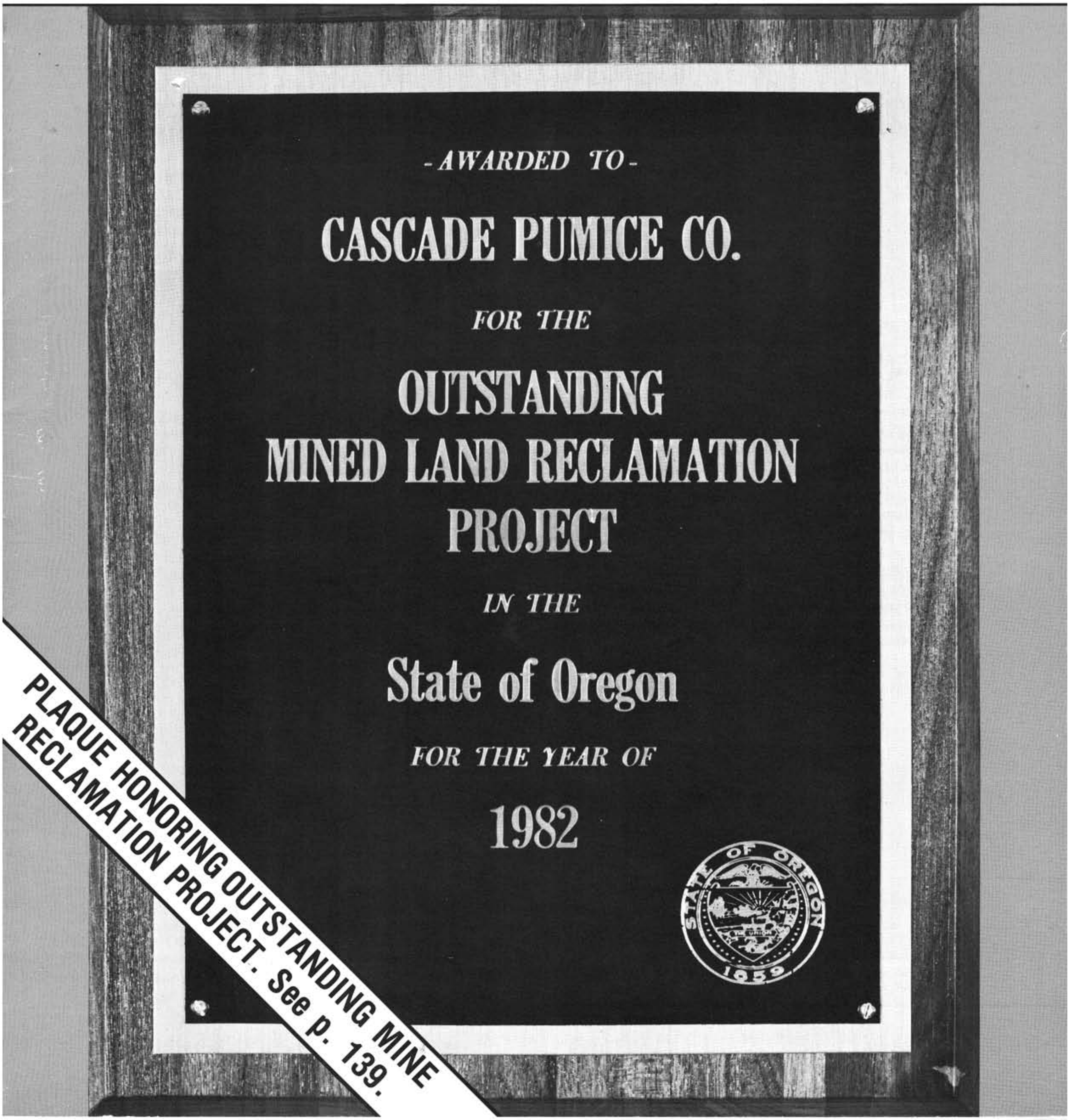

PLAQUE HONORING OUTSTANDING MINE RECLAMATION PROJECT. See p. 139.

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COVER PHOTO

Plaque awarded to Cascade Pumice Company, Bend, Oregon, winner of first annual award for outstanding surface mined land reclamation project in Oregon. Article beginning on next page discusses Oregon's surface mined land reclamation program and this award.

OIL AND GAS NEWS

Columbia County

The Libel 12-14 location listed last month for sec. 14, T. 6 N., R 5 W. was drilled and abandoned as a dry hole. Reichhold Energy has now drilled and completed Paul 34-32 in sec. 32, T. 7 N., R. 5 W. This well is ¾ mi southwest of the producer Longview Fibre 12-33 and was completed on November 13. Total depth is 2,698 ft. This producer, the tenth in the Mist Gas Field, tested at 1.4 million cubic feet of gas per day and is the first well to have most of the mineral ownership privately held. Rights on previous wells have been held by Columbia County.

Clatsop County

Oregon Natural Gas Development Company will decide after January 1, 1983, whether to redrill Patton 32-9 in sec. 9, T. 7 N., R. 8 W. The well is now suspended.

Recent permits

Permit no.	Operator and well name	Location	Status
225	Reichhold Energy Corp.; Adams 13-34	SW¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Application.

Northwest oil and gas newsletters

Three companies in Oregon publish newsletters with current information about oil and gas developments in the Northwest. Their names, addresses, and types of information are listed below.

Oregon and Washington Oil and Gas Report (Published monthly by Delores Yates LANDATA Reporting and Services, Box 393, Portland, OR 97207, phone [503] 227-3670.) Covers Oregon and Washington. Includes current information on oil and gas drilling, lease applications and leases issued, simultaneous filing and competitive sales, changes in State and Federal regulations, drilling reports, and other items of interest.

Northwest Oil Report (Published twice each month by John Newhouse and Dick Bowen, 4204 SW Condor, Portland, OR 97201, phone [503] 224-2156.) Covers Oregon, Washington, and western Idaho. Contains articles on oil, gas, and geothermal activities within each reporting period. Includes current information on drilling activities, Federal and State lease applications, geophysical activities, and Oregon Division of State Lands lease assignments.

Pacific Energy News (Published monthly by Scott Humphrey and Kurt Humphrey, Box 40045, Portland, OR 97240, phone [503] 222-6000.) Covers Oregon and Washington. Contains current information on oil and gas drilling permits and drilling activity updates; Federal leasing information, including parcels available, applications for parcels, and changes in rules; State leasing information, including results of State lease sales and updates on State rule changes for leasing and drilling; and samples of maps that are available through their office. □

CONTENTS

Cascade Pumice Company is Oregon's outstanding mined land reclamationist for 1982

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

Cascade Pumice Company of Bend, Oregon, was the unanimous choice of the selection committee for the first annual award honoring the outstanding surface mined land reclamation project in Oregon. In recognition of this distinction, the company received the plaque shown on the cover of this issue of *Oregon Geology*. Furthermore, theirs is the first name to be engraved on a perpetual plaque to be maintained by the Oregon Department of Geology and Mineral Industries. The selection was made by a committee composed of representatives from industry and environmental interests and this author.

Cascade Pumice Company, which is managed by Charles (Chuck) Clark, has recontoured, respread with topsoil, and restored to agricultural use over forty acres of mined land. Prior to mining, this land was, at best, lightly timbered, marginal grazing land. Now, after mining and reclamation, however, the land can also be used for other purposes, should it be desired and zoned accordingly.

Charles (Chuck) Clark (left), Manager of Cascade Pumice Company, Bend, Oregon, holds plaque naming Cascade Pumice as Outstanding Mined Land Reclamation Project in Oregon for 1982. Donald A. Hull (right), State Geologist, holds plaque on which names of each year's winners will be engraved.

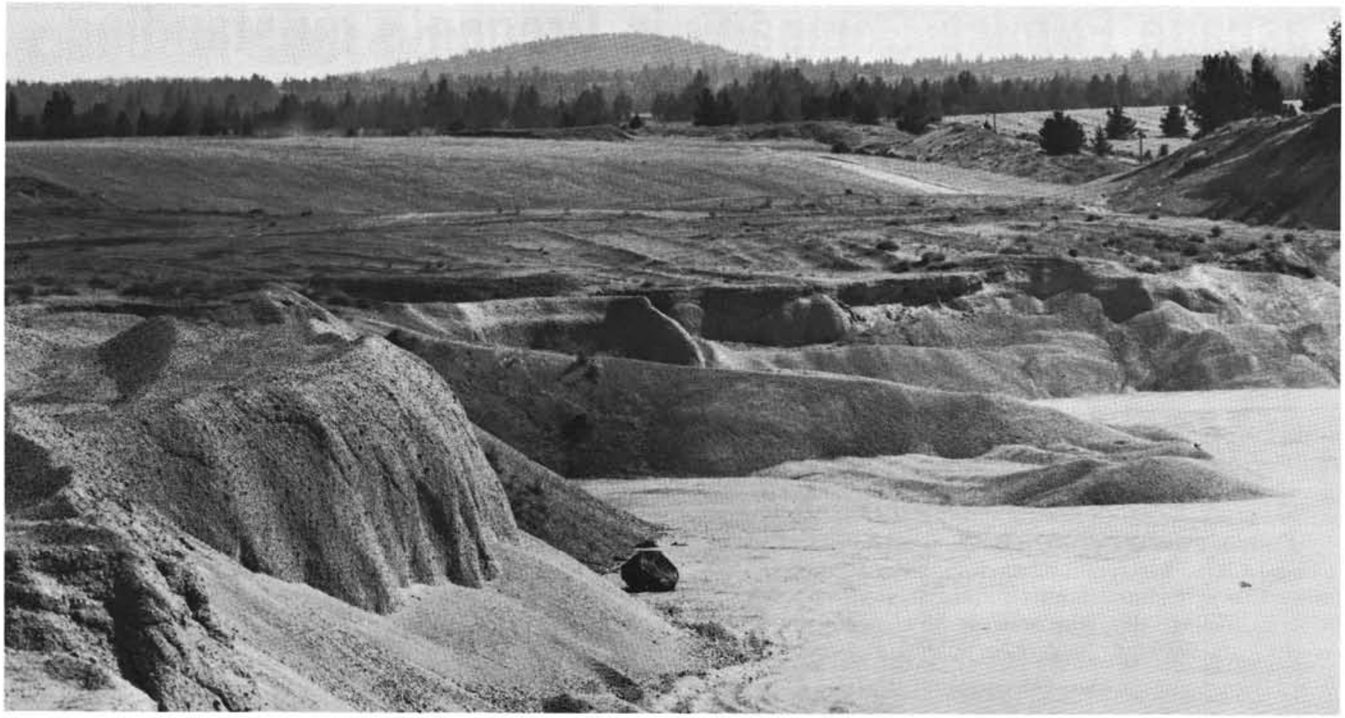
Unmined area, typical of conditions prior to mining, belonging to Cascade Pumice Company, near Bend, Oregon.

It is especially gratifying to see that the company's reclamation to the present can be considered as having been essentially voluntary, since the involved acreage was "grandfathered" (exempted) from the Surface Mined Land Reclamation Act.

This reclamation project is also an example of concurrent reclamation, accomplished during, rather than after, the mining operations. As successive cells are mined out, similar reclamation will follow. In the meantime, overburden and topsoil are being stored in a stable manner, until their later reapplication. Some leave strips and berms are also maintained as visual and acoustic barriers, as the mining operations continue.

Well-deserving runners-up in the newly created contest included North Santiam Sand and Gravel Company of Stayton, Wayne Spring, General Manager; and Coos County Highway

Stand of ryegrass on land that has been reclaimed after having been mined by Cascade Pumice Company.



Mining operations of Cascade Pumice Company, winner of the Outstanding Mined Land Reclamation Project award for 1982. A portion of one operational area is shown in foreground. In middle distance is reclaimed land which is comparable in grade to cultivated land shown in far right.

Department of Coquille, Wesley (Red) Clark, Coos County Roadmaster/Public Works Director. North Santiam Sand and Gravel converted worked-out pits to aquaculture and, since October 1981, has run a very successful operation of producing, processing, and marketing fresh and processed fish. The Coos County Highway Department mined gravel from a site near Bandon and then left three acres reclaimed and ready for the owner for planting of a cranberry bog.

Some of the criteria governing selection of the winning site were:

1. Compliance with the approved reclamation plan.
2. Imagination and/or innovation in accomplishing the planned reclamation.
3. Future value of the site.
4. Appropriateness to the local environment.
5. Safety.
6. Aesthetics.

The major goal of the Surface Mined Land Reclamation Act of 1972, as amended (ORS 517.750-517.990), is to develop a "future beneficial use" for surface mined land coincident with completion of mining. In practice, such development of beneficial use may also be concurrent with mining. In everyday terms, this means maintaining or enhancing the value of the mined acreage into the future. An additional goal is to leave sites reasonably safe and nonpolluting. To date, over 800 acres of Oregon lands have been reclaimed with the program.

The finalist sites this year well illustrate the very considerable diversity of uses to which mined areas in Oregon are finally assigned. Much acreage goes to various agricultural applications such as dry grazing areas, stock tanks, cultivation, and at least two stock shelters and feed lots. For forestry applications, some areas are replanted to trees, and a few sites are reservoirs for fire fighting. Water-related uses in addition to those listed above include marinas and recreational fisheries, sites related to irrigation, and areas for wildlife management, such as wetlands, nesting areas, shelter, and food resources. Finally, some sites are used for housing and public buildings (for example, the new building for the Multnomah County Division of Operations and Maintenance is located in one of the County's old gravel pits), for landfills and parks, industrial-commercial construction, and stockpile and equipment pads.

Reclamation involves a wide spectrum of interdisciplinary skills including knowledge of agriculture, forestry, geology, wildlife management, botany, meteorology and effects of weather, water (surface and subsurface), processing requirements essential to different mineral commodities, poisons (natural and introduced), and tools such as ground control or

Leave strip and berm between road and pit at Cascade Pumice Company. The berm is made of stored topsoil overburden that can be respread as a seed base when mining is completed. In the meantime it provides a visual screen and sound barrier.

One of North Santiam Sand and Gravel Company's three trout-rearing ponds situated in mined-out sand and gravel pits near Stayton, Oregon. This company was one of the two runners-up for this year's award for the Outstanding Mined Land Reclamation Project.

stabilization devices, tackifiers, and flocculants. Some knowledge of landscape architecture is often useful.

It is important to note that although the Oregon mineral industry pays the cost of the Mined Land Reclamation Program as well as costs of the actual reclamation, good results have been obtained, and the attitude and cooperation of most of the mineral industry operators are highly commendable.

Support and a large amount of resource material are available both to the operator who conducts reclamation and to specialists, consultants, and professionals who advise and regulate. The National Sand and Gravel Association has made professionally prepared reclamation publications available to its membership. The American Planning Association has similarly prepared and offered publications concerning reclamation to its member planners. Industrial and professional journals frequently provide excellent articles on many aspects of reclamation. For example, *Rock Products* is currently running an outstanding series of articles on reclamation. Furthermore, many universities now have curriculums specifically designed to prepare for entry into the reclamation profession, and some already have departments exclusively for that field.

A fairly substantial reclamation industry has already evolved. A variety of reclamation consultants provide services ranging from providing baseline data to final plans. Reclamation suppliers provide such essential products as seeds, including some hard-to-find species, many ground-stability devices, tackifiers, dust-control chemicals, and flocculants.

Reclamation is obviously an expensive and sometimes very complex function. It is nearly always most economically and usually most effectively accomplished by preplanning and a continuous awareness, while mining, of the ultimate goals. The values of successful reclamation and of profitable, new uses for a mined site are often surprising and can be quite considerable, both to the land owner and to the community.

We are now ready to receive the names of the nominees for the 1983 award. Anyone may nominate a site for consideration. □

Wanted: theses on Oregon geology

The Oregon Department of Geology and Mineral Industries (DOGAMI) has a policy of collecting systematically master's and doctoral theses that provide new information on Oregon geology. Once DOGAMI has decided that acquisition of such a study is desirable, the Department will, for receipt of two bound copies, pay the author $50 per copy of a master's thesis and $75 per copy of a doctoral dissertation. Information about such work in progress or completed is always welcome at DOGAMI (see addresses and phone numbers on first inside page of this issue). □

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Miners' candlesticks—a glimpse of yesterday's mining industry

by N.S. Wagner, geologist, retired, Oregon Department of Geology and Mineral Industries; present address, 2624 First Street, Baker, Oregon 97814

FOREWORD

Early lode mining in Oregon spanned the period during which candles constituted the dominant source of illumination in virtually all western lode mines. During this period, Oregon had a notable number of inventive miners who were granted patents covering improvements to the holders for these candles. It is as a memorial to the creative efforts of these individuals that the following summation of the "candlelight era" is offered.

INTRODUCTION

The need for illumination in underground mines is met amply today by electric cap lamps powered by rugged, rechargeable batteries worn on the belt. These lamps produce either area or spot lighting at a flick of a switch, and the batteries deliver an abundance of reliable illumination over a full shift or more with one charge.

So universal has the use of these electric lamps become that to many readers it may seem almost unbelievable there are miners still living who mined by candlelight. It is nevertheless a matter of record that the last patent granted by the U.S. Patent Office for a miners' candlestick dates as recently as December 1917 (Ramsdell and Wagner, 1982). Furthermore, it is likewise a documentable fact that candles marketed expressly for use with miners' candlesticks were still listed as "for sale" items in some mining supply catalogs as late as 1938 (e.g., Basche-Sage, 1938).

THE "CANDLELIGHT ERA"

Throughout civilized time, from King Solomon's day to the opening decades of the present century, a diverse assortment of wick lamps dominated the mine-lighting scene. Fueled with greases, lard, or whatever combustible oils were available, such lamps yielded minimal amounts of uncertain light along with unsavory odors and an abundance of dirty, greasy smoke. Although highly inefficient and undesirable on most counts, they nevertheless, in one form or another, constituted the prevailing source of mine lighting worldwide. Furthermore, they did so even though tallow candles were known to mankind before the time of the Romans. It was not until better quality, harder, slower burning, and melt-resistant candles were developed that the wick-type lamps were replaced by superior forms of lighting. In fact, a substantial amount of the metals used during World War I must have been mined by candlelight.

The date on which candles first became a dominant source of illumination in mines is not known. In this country, the use of candles for subsurface lighting coincides pretty well with the development of lode mining in the western states. Furthermore, their use has a distinctly western flavor in that eastern coal miners continued to use their modern equivalents of the ancient wick-type lamps, even when the use of candles had become firmly established west of the Mississippi. The beginning of the "candlelight era" as described in this article can thus be said to date sometime after the middle of the last century, probably around 1860-1865.

There are three circumstances which combined to trigger, or at least account for, the rather sudden popularity of candles at this time. First, mass-produced candles began to appear in the mid-1850's. Joseph Morgan had invented the first continuous wicking and piston-ejection-type candle-molding machine in 1834. Numerous improvements by others had followed in rapid succession, and the mechanization thus introduced, along with rapid improvements to the machines themselves, had wrought far-reaching changes in the candle-making industry. After all, candles had been largely hand-made, home-made kitchen products before then or, when not home-made,

Oil/wick lamps from pre-candle era (left to right): Clay lamp (Roman period); stirrup lamp (probably French-made but used at Morro Cocha Mine, Peru); Betty lamp (double "crusie" with covering lid, background unknown); open-type double "crusie" (from historic Almaden mercury mining area of Spain); Frog lamp (German); two wick-type cap lamps (typical turn-of-the-century, eastern U.S.).

Bolivian miner wearing lighted "crusie" -type oil lamp on his cap (from Herndon, 1854).

had been the products of commercial plants in which inordinate amounts of manual labor and tedious handling still prevailed.

The second circumstance bearing on the sudden rise in popularity of candles as industrial tools during the closing decades of the last century would today be described as "Research and Development." During the middle of the last century, some talented scientists began seriously looking into the chemistry of candle ingredients to an extent never done before. As a result, they developed stearin candles, a type which possessed physical properties superior to any known previously.

The third circumstance contributing to the revolution in candle making was that large quantities of paraffins became commercially available for the first time in history during the latter decades of the last century, at the same time when facilities for mass producing candles and the research trends with respect to quality enhancement were being nicely perfected. Derived from coal and/or oil-refinery residues, these paraffins were produced by the new and growing coal and oil companies. So greatly did these mineral-based paraffins contribute to the burning control and light output of candles that their use as a candle ingredient soon became important, and some oil companies of the period actually became candle suppliers to the mining industry in the capacity of primary manufacturers of miners' candles.

Once machine-produced candles of an upgraded quality were available to miners at reasonably affordable prices, can-

Wooden candle box, Standard Oil Company of New York. Original in restored Kam Wah Chung Company building, old Chinatown, John Day, Oregon.

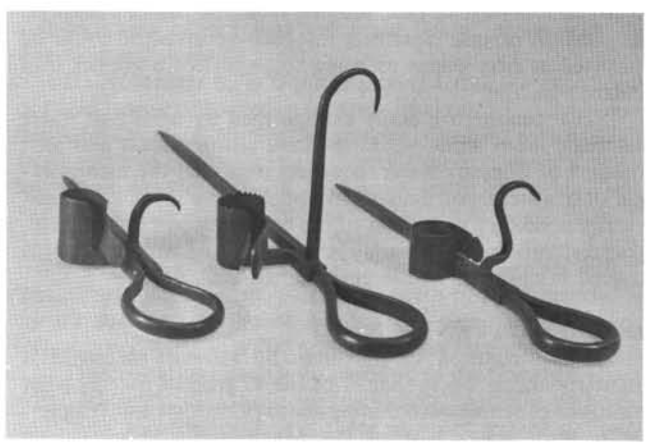
dle use as a source of underground illumination expanded rapidly. One good measure of this expanded use is that between 1872 and 1917 the U.S. Patent Office granted a known total of 87 patents for miners' candlesticks (Ramsdell and Wagner, 1982). Calculated as a yearly average, this amounted to an issuance of about two patents during each of the 45 years between the first and last granted patents.

TYPICAL BLACKSMITH-MADE CANDLESTICKS

The earliest candlestick made for mining use is believed to have been a simple spikelike affair, pointed on one end and with a loop fashioned on the other to serve as a socket for the candle. The purpose of the spike was to facilitate wedging the candlestick into strategically located timbers or rock crevices at the user's work site.

Primitive candlesticks of this blacksmith-made type were supplanted very soon by a more sophisticated product. The improved version featured a handle where the socket of the above-described type had been, with the socket itself relocated to a position on one side of the spike, roughly midway between the spike point and the back end of the handle. In addition, a vertical hook 3-4 in. high was added to the spike at a point roughly opposite the relocated socket. This hook enabled the user to hang the candlestick from a nail or from any protruding surface.

Hand-forged candlesticks conforming to this pattern are generally classified as typical miners' candlesticks. However,



Typical blacksmith-made miners' candlesticks. Note differences in size and shape of hooks and sockets.

because a vast number of individual craftsmen were engaged in their making, no exacting specifications can be offered here. After all, each maker was an artist in his own right when it came to details of size and styling. Thus, candlesticks of this basic design varied from 5 to as much as 18 in. in length, although they commonly ranged from 10 to 12 in. Handles and hooks also differed greatly in shape, size, and styling between makers. Appearance varied appreciably, in that some specimens could be classed as plain, functional, unadorned tools, while others exhibited decorative features reflecting blacksmithing expertise of almost unbelievable attainment. Some specimens were embellished with handcrafted miniature mining tools, lodge emblems, and other forms of decoration which served no functional purpose whatsoever other than to bolster the maker's pride in his craftsmanship and the purchaser's pride in ownership. While most candlesticks of this type were steel, some few were hammered out of copper or even silver.

PATENTED CANDLESTICKS

The patented varieties of miners' candlesticks were usually made in machine shops or foundries, and they exhibited a commercial appearance, accordingly. All patented candlesticks included such basic elements as spikes, hooks, handles, and sockets; however, the manner in which they did so showed great variations, to the extent that in some extreme instances the final product came close to resembling the familiar Swiss Army knife with 20 built-on accessories. For example, a large number of the early inventors patented designs by which the hooks and spikes could be pivoted and/or telescoped back into the handle so as to convert the otherwise ungainly implement into a reasonably manageable pocket piece for carrying and storage. Similarly, many of the inventors developed ways of converting the basic candlestick into a multipurpose tool, as is indicated by the number of patents covering such built-in accessories as cap crimpers, fuse cutters, and even knife blades. Indeed, the multiplicity of ways devised for accomplishing these two objectives alone accounted for about half of the 87 granted patents.

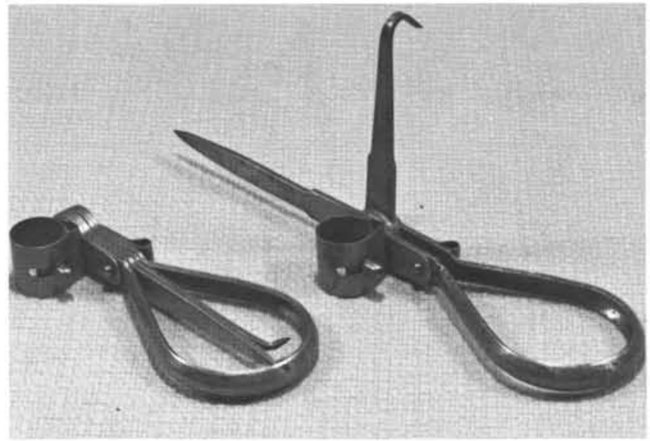
Among the remaining patents were several designs for umbrellalike canopies, to protect the candle from dripping water in wet mines, and socket-hook assemblies that could be detached from the spike, for independent use as cap-mounted units. Fire-conscious inventors perfected snuffers designed to extinguish the flame automatically if a candlestick was carelessly left unattended with the candle still burning.

Given such diversity of inventive inspirations, it follows that while some of the patented end products are easily recognized as being miners' candlesticks, others are not, until scrutinized closely. In fact, judging from the patent drawings, the creation of one extremely imaginative inventor could be dismissed at first glance as being some sort of a gopher trap (Patent 656,209).

Since candles are easily extinguished by wind and water and since many mine workings have strong drafts and vast amounts of dripping water, it would seem that the incorporation of a waterproof match box should have rated as a high-priority accessory with most of the early inventors. Strangely, however, provisions for a reserve supply of dry matches is covered in only two of the granted patents.

OREGON PATENTEES

The distribution of patentees by state of residence is singularly impressive in that 77 of the 87 granted patents went to citizens of ten western mining states (Ramsdell and Wagner, 1982). Most states east of the Mississippi had no citizen patentees at all, while Ohio and Pennsylvania had but one each. Only those areas which were associated with the Great



Peterson-Fielding foldable candlestick, Patent 735,578, shown folded and extended. Made around 1904 or 1905 in Grants Pass, Oregon.

Lakes copper and iron mines fared better. These were Illinois, Michigan, Minnesota, and Wisconsin which, along with Canada, had a total of eight patents between them. Among the western states, Colorado led the pack with a total of 24 patentees. California placed next with eleven, followed by Montana with nine.

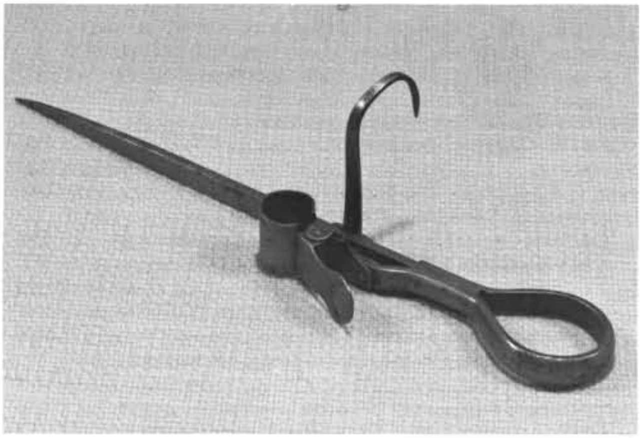
Oregon tied for fifth place with Utah, each having five patentees. The names of the Oregon patentees are as follows:

Name	City	Patent number	Grant date
John Jones	Oregon City	270,316	Jan. 1883
Samuel Peterson and Cornelius Fielding	Grants Pass	735,578	Aug. 1903
Edgar Curtiss	Baker City	766,599	Aug. 1904
Elisha Weed	Medford	824,609	June 1906
Milton Gault	Medford	883,307	Mar. 1908

Each of the above-listed Oregon patentees is to be credited with having contributed substantially meaningful improvements to the design and utility of miners' candlesticks. Because of space limitations, however, only two examples can be pictured and described here. Those selected are the Peterson-Fielding patent of 1903 and the Edgar Curtiss patent of 1904. Both were produced commercially, with the result that fine specimens of each are available for illustrative purposes.

The Peterson-Fielding candlestick is one of the neatest and most sturdily constructed of all the several patented fold-up types. No information is currently at hand concerning the Peterson-Fielding manufacturing facility, other than that it was located in Grants Pass. There is, however, an as yet unconfirmed report to the effect that 1,000 of these sticks were made and shipped to Australia by individuals who leased the plant and temporary manufacturing rights to the patent around 1912.

The primary patent feature of the Curtiss product is a two-piece, spring-loaded socket functionally comparable to the clip on a clipboard. While sockets on most miners' candlesticks of both the patented and unpatented variety had some sort of a provision for making the emplacement and removal of a candle relatively easy, Curtiss' spring-loaded clip type constituted a major improvement. Another aspect of the Curtiss product is that it was so designed that all component parts such as the spike, hook, handle, and socket unit could be fabricated in quantity in finished form for future assembly as



Edgar Curtiss candlestick, Patent 766,599, with two-piece, clip-type socket. Made around 1905 or 1906 in Baker City, Oregon.

and when needed. And, unlike the case with most other candlesticks, this final assembly consisted simply of riveting the component parts together, which eliminated the tedious and costly need for brazing. The components were made in a West Coast machine shop; they were assembled by Curtiss in his home town of Baker, then known as Baker City, and the product was marketed either plain or nickel-plated.

CONCLUSION

No closing paragraph can be written concerning the "candlelight era" without re-emphasizing three facts. One is that the era was very real. The second is that it was distinctively western. And finally, its tapering-off phase came far closer to the present than many readers might have realized before learning the dates on which patents were granted for miners' candlesticks and the even later dates on which miners' candles were still being advertised as "for sale" items in various mine-supply catalogs. After all, December 1917 wasn't all that long ago, and the decade of the 1930's is just barely yesterday.

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Herndon, W.L., and Gibbon, L., 1954, Exploration of the valley of the Amazon: Executive Document No. 53, 33rd Congress, 1st session, Serial Set No. 722, 339 p.

Ramsdell, J.D., and Wagner, N.S., 1982, Patents, miners' candlesticks (2nd ed.): Carson City, Nev., privately published, unpag. □

GSOC luncheon meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

December 17—*Portland's Leach Botanical Park*, by Charleen M. Holzwarth, Secretary, Leach Garden Friends.

January 7, 1983—*Roadside Geology of Oregon*, by Donald D. Barr, President, GSOC, 1968. □

Corrections

The first sentence in the October "Oil and Gas News" should be changed to read "There has been no drilling at the Mist Gas Field since last month." The location of Oregon Natural Gas Development Company's Patton 32-9 well in Clatsop County was incorrectly given in the November "Oil and Gas News" and should be changed to sec. 9, T. 7 N., R. 8 W. □

Landscape architecture students eligible for quarry beautification competition

The National Crushed Stone Association (NCSA), National Sand and Gravel Association (NSGA), and American Society of Landscape Architects (ASLA) are sponsoring a competition for the best design for beautification and reclamation of a sand and gravel or crushed stone mining site. Entry is open to any school with landscape architecture degree programs in the United States or Canada. Eligibility is limited to undergraduate seniors and graduate students. Prize money will be awarded to the student and his department of landscape architecture.

Students entering the competition are to focus their attention on a proposed or existing site. Following an analysis of the site, they are to develop plans to reduce the adverse effects of the operation on its surroundings, progressing by step-by-step phases to cost-effective final reclamation and end use. Their entries will present a solution containing three distinct components (site analysis, operation beautification plan, and long-term reclamation plan), each on a separate board, along with a 5,000-word narrative description of the project, including a definition of the problem, discussion of plans, and estimated cost analysis. All entries become the property of NCSA or NSGA, who will also assist students in locating potential subjects for their projects.

First entry forms must be submitted by March 18, 1983; final entries by April 8, 1983. Judging will take place in early May 1983. For further information, contact the National Sand and Gravel Association, 900 Spring Street, Silver Spring, MD 20910, or the National Crushed Stone Association, 1415 Elliott Place, NW, Washington, DC 20007. □

PSU student AIME elects new officers

At its October 19, 1982, meeting, the Portland State University Student Chapter of the AIME elected its new officers for the current school year. President is Krista McGowan, Vice President is Alex Dees, and Secretary-Treasurer is Carolyn Browne. Faculty Advisor is Michael L. Cummings, Earth Sciences Department, Portland State University. □

Series of meteors lights up November skies

Six fireballs were observed in Pacific Northwest skies during a 72-hour time interval early in November. Dates, times, and locations of sightings are listed below, along with the direction and angle of flight.

(1) November 6, 7:00 p.m., Beaver Creek, Oregon; path of flight from east to west at an angle of about 15°. (2) November 7, 6:10 p.m., Chehalem Mountains, Oregon; path of flight from east to west parallel to the earth's surface; made a swishing sound. (3) November 8, 5:15 a.m., south of Boeing Field, Seattle-Tacoma area, Washington; path from north to south parallel to earth's surface. (4) November 9, 6:30 a.m., Cedar Hills, Oregon; going to the southeast. (5) November 9, 6:52 a.m., Parkrose, Oregon; path from north to south parallel to earth's surface. (6) November 9, 6:45 p.m., Oregon City, Oregon; dropping at a 20° angle and breaking up.

These sightings have been reported to the Scientific Event Alert Network, Smithsonian Institution. Anyone with any additional information about these or other meteor sightings should contact Dick Pugh, Cleveland High School, 3400 SE 26th Ave., Portland, OR 97202, phone (503) 233-6441. □

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