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Main Office: 910 State Office Building, 1400 SW Fifth Ave., Portland 97201, phone (503) 229-5580, FAX (503) 229-5639.

Baker City Field Office: 1831 First Street, Baker City 97814, phone (503) 523-3133. Howard C. Brooks, Resident Geologist.

Grants Pass Field Office: 5375 Monument Drive, Grants Pass 97526, phone (503) 476-2496. Thomas J. Wiley, Resident Geologist.

Mined Land Reclamation Program: 1534 Queen Ave. SE, Albany 97321, phone (503) 967-2039. Gary W. Lynch, Supervisor.

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Information for contributors

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The style to be followed is generally that of U.S. Geological Survey publications. (See the USGS manual *Suggestions to Authors*, 6th ed., 1978 or recent issues of *Oregon Geology*.) The bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the acknowledgments.

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

Cover photo

Green calcareous paleosols of the Turtle Cove Member of the John Day Formation, Foree Unit, John Day Fossil Beds National Monument.

The area of the John Day Fossil Beds National Monument in Wasco County, Oregon, is a major point of interest in the field trip guide beginning on the next page.

OIL AND GAS NEWS

Oil and gas leasing activity

During April, Columbia County held an oil and gas lease sale at which Nehama and Weagant Energy Company of Bakersfield, California, acquired three leases consisting of 677 acres located in the Mist Gas Field. All were purchased for $2.50 per acre. The State of Oregon held an oil and gas lease sale during May, at which Nehama and Weagant acquired three leases comprising 897 acres located in Clatsop County, adjacent to the Mist Gas Field. All were purchased for $1.00 per acre. The USDA Forest Service plans to hold an oil and gas lease sale for acreage in the Ochoco National Forest in central Oregon. Details can be obtained from Deborah Tout, Ochoco National Forest, P.O. Box 490, Prineville, Oregon 97754.

NWPA annual symposium scheduled

The annual field symposium of the Northwest Petroleum Association (NWPA) will be held September 8-10 and will discuss the geology and petroleum potential of the Bellingham Basin, northwestern Washington and southwestern British Columbia. The symposium will include talks and presentations and a day in the field. Contact the NWPA, P.O. Box 6679, Portland, Oregon 97228-6679, for further information.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
452	Nehama & Weagant Columbia Co. 23-35-75 36-009-00278	SW¼ sec. 35 T. 7 N., R. 5 W. Columbia County	Permit; 3,400.
453	Nehama & Weagant Columbia Co. 42-3-65 36-009-00279	NE¼ sec. 3 T. 6 N., R. 5 W. Columbia County	Permit; 3,300.
454	Nehama & Weagant Columbia Co. 22-2-65 36-009-00280	NW¼ sec. 2 T. 6 N., R. 5 W. Columbia County	Permit; 3,000.
455	Nehama & Weagant Columbia Co. 14-32-75 36-009-00281	SW¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Permit; 3,500.
456	Nehama & Weagant Adams 31-34-75 36-009-00282	NE¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Permit; 3,600.
457	Nehama & Weagant Columbia Co. 23-31-65 36-009-00283	SW¼ sec. 31 T. 6 N., R. 5 W Columbia County	Application; 2,340.
458	Nehama & Weagant Columbia Co. 34-31-65 36-009-00284	SE¼ sec. 31 T. 6 N., R. 5 W. Columbia County	Application; 2,110.
459	Nehama & Weagant Columbia Co. 44-8-64 36-009-00285	SE¼ sec. 8 T. 6 N., R. 4 W. Columbia County	Application 1,870
460	Nehama & Weagant LF 21-31-65 36-009-00286	NW¼ sec. 31 T. 6 N., R. 5 W. Columbia County	Application; 1,950.
461	Nehama & Weagant CER 14-26-64 36-009-00287	SW¼ sec. 26 T. 6 N., R. 4 W. Columbia County	Application; 2,850

□

A field guide to mid-Tertiary paleosols and paleoclimatic changes in the high desert of central Oregon—Part 2

by Gregory J. Retallack, Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403

This field trip guide was prepared for the Theme Meeting of SEPM (Society for Sedimentary Geology) to be held August 15-18, 1991, in Portland, Oregon. The theme of this meeting is "Continental margins—sedimentation, tectonics, eustasy, and climate." Part 1 of the guide for the two-day field trip appeared in the last (May 1991) issue of *Oregon Geology* and ended with the return to John Day to spend the night. This second part presents the guide for the second day and the conclusion of the paper. *—Editor*

EXCURSION ITINERARY FOR SECOND DAY

Leave John Day heading west on U.S. Highway 26. The valley of the John Day River is flanked to the south by Triassic and Jurassic schists and to the north by a Miocene and Pliocene sequence of white to gray silty claystones and volcanic ashes, within which the Rattlesnake ash-flow tuff forms a prominent scarp. Picture Gorge Basalt in a gorge south of the highway at a point 16 mi west of John Day has yielded a K-Ar age of 15.8 m.y. (Evernden and others, 1964, corrected by method of Dalrymple, 1979). The overlying gray to brown, clayey Mascall Formation is also middle Miocene in age. The prominent rhyodacitic ash-flow tuff of the Rattlesnake Formation in this area has a corrected radiometric age of 6.6 m.y., so that the tuffaceous sediments enclosing it are late Miocene and Pliocene in age. This ash-flow tuff represents a catastrophic volcanic event and is here over 100 mi distant from its source in the Harney Basin south of Burns (Oles and others, 1973).

In the river bank near the roadside rest stop that is immediately west of the bridge across the John Day River about 11 mi west of Mount Vernon is a locality for fossil leaves in the middle Miocene Mascall Formation (Chaney, 1948; Chaney and Axelrod, 1959). The ten most common species at this locality, comprising 78 percent of the flora, are (in order of decreasing abundance): Swamp cypress (*Taxodium distichum*), black oak (*Quercus pseudolyrata*), hickory (*Carya bendirei*), sycamore (*Platanus dissecta*), black oak (*Quercus merriami*), maple (*Acer bolanderi*), redwood (*Sequoia heerii*), maidenhair tree (*Ginkgo adiantoides*), box elder (*Acer negundoides*), and elm (*Ulmus speciosa*). This mixed broadleaf and conifer assemblage is an indication of cool-temperate, seasonal conditions. Paleoclimate was still very different from the high-desert climate of the present day and was more like the present-day climate of southern Indiana or Ohio. By using foliar physiognomic data from the Mascall flora, Wolfe (1981b) estimated a mean annual temperature of 9° to 10 °C and a mean annual range of temperature of 12° to 23 °C. Winters may have been consistently snowy by this time.

About 4 mi west of Dayville on Highway 26, look for and turn onto an unsealed road leading southwest onto the high terrace.

STOP 9. Picture Gorge overlook

One-half mile south of U.S. Highway 26 on Day Creek Road, 4 mi west of Dayville (NE¼NE¼ sec. 29, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle), we find a spectacular view of Picture Gorge and overlying sedimentary rocks (Figure 6). The Gorge itself is formed of tholeiitic flood basalts of the middle Miocene Picture Gorge Basalt of the Columbia River Basalt Group. Here the flows dip to the southeast and have been deeply incised by the John Day River, which was an antecedent stream to this tectonic deformation. Although the scene makes a fine photograph, this is not the origin of the name Picture Gorge: that name is based on the early discovery of Indian pictographs within the gorge.

Overlying the basalt with a slight angular discordance is a thick sequence of gray and brown tuffaceous alluvial sediments of the Miocene Mascall Formation. In places, diffuse dark layers of paleosols and light-colored, prominently outcropping sandstones of paleochannels can be seen. The formation onlaps tilted basalts, so that some deformation had been initiated during Miocene time. The blocky, mesa-forming unit overlying the Mascall Formation is welded tuff of the Pliocene Rattlesnake Formation. It onlaps the Mascall Formation with an angular discordance that resulted from continued Pliocene tilting.

Just over the bank here, in the Mascall Formation, Downs (1956, highway locality) reported fossil mammal remains including three-toed horse (*Merychippus seversus*) and pronghorn antelope (*Blastomeryx, Dromomeryx*) typical of middle Miocene faunas (Barstovian North American land mammal "age"). These are considered grassland-adapted mammals because of their high-crowned teeth and elongate limbs with hard hooves. Such open vegetation is also indicated by the thin, gray, calcareous paleosols visible in badlands of the

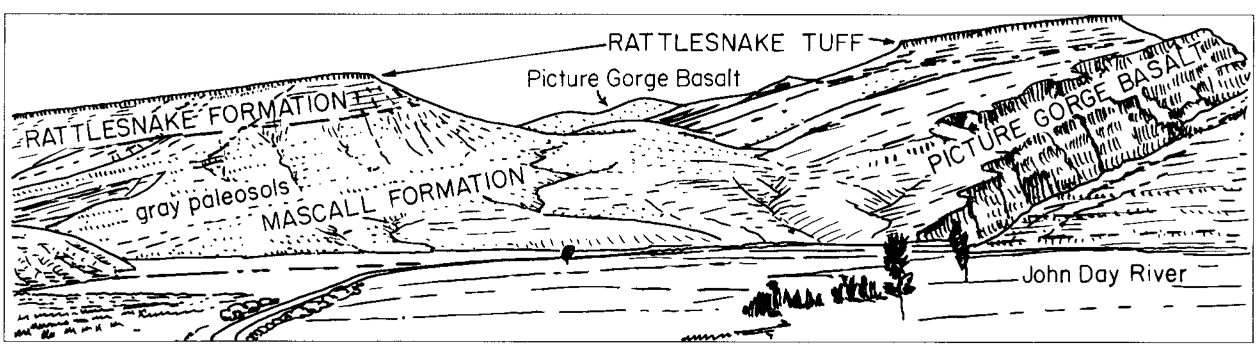

Figure 6. Geological sketch of Picture Gorge, viewed from the east.

Mascall Formation to the west, although it would not have been suspected from the Mascall flora already discussed from east of Dayville (Chaney, 1948). That broadleaf forest and swamp vegetation was probably widespread around lowland lakes and streams, and its fossil leaves accumulated and were preserved in them. On dry, grassy parts of the landscape, however, plant material decayed in the oxidized, calcareous soil where bones of animals accumulated.

The Rattlesnake Formation in Cottonwood Creek to the west also has yielded fossil mammals (Merriam and others, 1925), principally one-toed grazing horses (*Pliohippus spectans*) and three-toed horses (*Cormohipparion occidentale*) of late Miocene age (Hemphillian land mammal "age").

En route

Return to Highway 26 and continue west into Picture Gorge.

STOP 10. Picture Gorge Basalt and paleosols

Road cuts 0.5 mi northwest of the entrance to Picture Gorge (NW¼SW¼ sec. 17, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle) show prominent red paleosols dividing flows of the Picture Gorge Basalt of the middle Miocene Columbia River Basalt Group. Red paleosols are widespread between flows in this area and allow flows to be distinguished readily. The paleosol profile just above road level is almost 2 m thick and appears to have been developed on a scoriaceous upper portion of the flow. The top of the profile is clayey and contains sparse root traces and strongly weathered fragments of basaltic scoria. This kind of clayey soil is formed over a considerable period of time (several tens of thousands of years) under woodland or forest in humid to subhumid climates (Retallack, 1990). Current radiometric estimates on the geological time represented by the Columbia River basalt allow periods on the order of 20,000 years between eruptions (Hooper and Swanson, 1990). These reddish interflow zones have been attributed entirely to baking of flow tops by the succeeding flow. While baking may have hardened and reddened the paleosols and added zeolites and other highly alkaline minerals to them, it is unlikely to have generated their clayey texture, soil structure, primary oxidation, root traces, and other weathering features.

En route

Continue on Highway 26 until it turns off to the west; then follow Highway 19 to the north.

STOP 11. Sheep Rock Overlook

Sheep Rock is a prominent conical hill, and an overlook is well signposted along Oregon Highway 19, north of its intersection with U.S. Highway 26 in Picture Gorge (NW¼NW¼ sec. 8, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle). This hill is capped by middle Miocene Picture Gorge Basalt of the Columbia River Basalt Group (Figure 7). Also exposed is Oligocene to early Miocene John Day Formation, which is here divided into characteristically colored members (Fisher and Rensberger, 1972). These colors reflect paleosols of different paleoenvironments that have suffered different kinds of alteration after burial. The division of the John Day Formation into distinctly colored members as seen here is not possible in all locations where the formation crops out.

At the base of the exposed sequence along the river to the north are red claystones of the Big Basin Member of the John Day Formation. This is presumably early Oligocene in age, but only a fragment of entelodon jaw (*Archaeotherium*) has been reported at this stratigraphic level (Evernden and others, 1964). These red noncalcareous paleosols were not generally suitable for the preservation of bone. White bands interbedded with the red claystones are fresh beds of volcanic ash. These ashes represent the parent material of most of the paleosols of the John Day Formation, here oxidized to brown or red clay under former humid forest and probably reddened further by dehydration of ferric hydroxides (as commonly documented for paleosols; G.S. Smith, 1988; Retallack, 1990). As climate dried during the Oligocene and Miocene, this ash was less and less altered within soils under drier and sparser vegetation.

Above the red beds are the green calcareous claystones and siltstone of the Turtle Cove Member. As already discussed (Stop 8), fossil soils, mammals, snails, and hackberries at this stratigraphic level are evidence of a lowland mosaic of woodland and wooded grassland.

The prominent dark-brown unit halfway down the slope of Sheep Rock is a thick and extensive rhyolitic welded tuff. This represents a catastrophic eruption of a large ash-flow tuff from a vent in the Ochoco Mountains to the west (Robinson and others, 1984).

Buff-colored siltstones near the top of the sequence are the Kimberly Member of the John Day Formation. These alluvial deposits contain numerous brown calcareous paleosols, probably formed under a mosaic of woodland and wooded grassland.

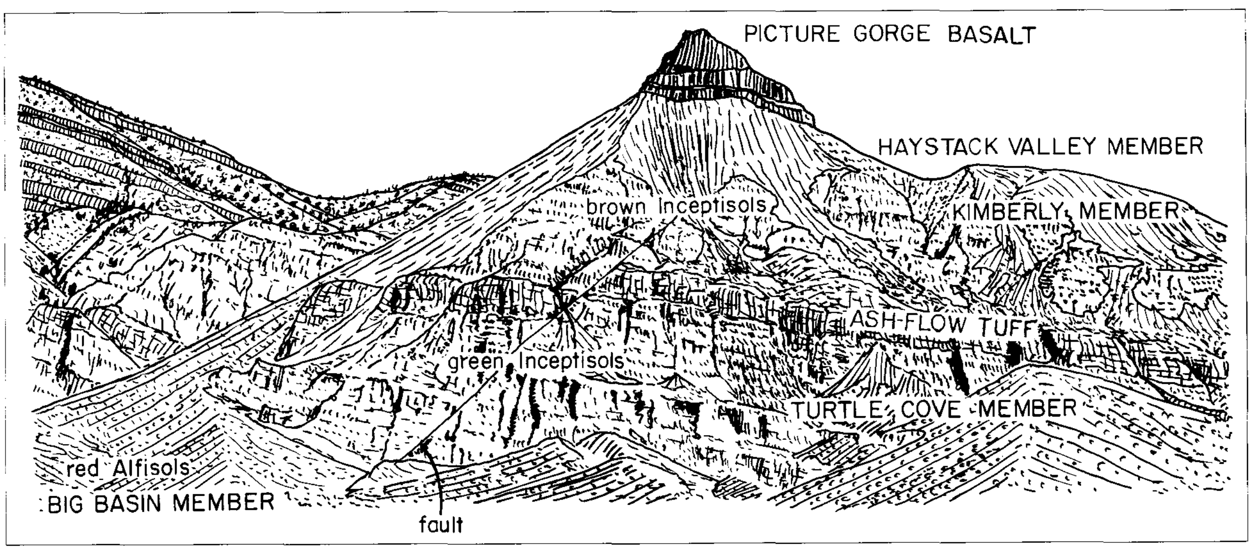

Figure 7. Geological sketch of Sheep Rock, viewed from the west.

The mammalian fauna of the Kimberly Member is diverse and includes hoglike oreodons (*Promerycochoerus superbus*), camels (*Paratylopus cameloides*), and tapirs (*Protapirus robustus*). This new fauna represents a significant advance in adaptations for open country, as in similar faunas in other areas of North America (Hunt, 1985) of early Miocene age (late Arikareean and Hemingfordian land mammal "ages"; Rensberger, 1983; Prothero and Rensberger, 1985).

STOP 12. Cant Ranch Visitor Center

North of Sheep Rock Overlook is the Visitor Center for John Day Fossil Beds National Monument at the old Cant Ranch (NE¼SW¼ sec. 6, T. 12 S., R. 26 E., Picture Gorge 15-minute quadrangle). Displays on the geology and paleontology of the mid-Tertiary sequence exposed in the John Day Valley and a fossil preparation laboratory are worth a visit. Maps and publications on the natural history of this region can be purchased here.

En route

Continue back south on Highway 19 into Picture Gorge, then west on U.S. Highway 26.

STOP 13. Mascall paleosols

A long, low road cut south of U.S. Highway 26, 2 mi west of its junction with Oregon Highway 19 (SE¼NE¼ sec. 24, T. 12 S., R. 25 E., Picture Gorge 15-minute quadrangle) reveals alluvial sediments and volcanic ash of the Miocene Mascall Formation. Remains of three-toed horse (*Merychippus seversus*) have been found in this formation 0.3 mi southwest of here (Rock Creek locality of Downs, 1956). White volcanic ash forms prominent, white bedded units, 3 m above the base of the cut. This ash was derived from Miocene volcanoes in the present area of the Western Cascades. Underlying the ash are three moderately developed paleosols (Inceptisols). They have thin (10 to 20 cm), yellowish-brown upper (A) horizons, with fine soil structure (granular peds of U.S. Department of Agriculture, 1975), over light-yellowish, weakly calcareous subsurface (Bk) horizons.

Calcareousness of the profiles is compatible with a subhumid climate. Their simple profile form and pattern of root traces are most like those found now under wooded grassland, a conclusion supported by dental and cursorial adaptation of mammal fossils found in the Mascall Formation. Topographic relief of these paleosols was probably low, but they show no mottles or restriction of rooting depth that might indicate waterlogging. Their parent material was air-fall ash from the Western Cascades mixed with rock fragments of local Mesozoic schists and sandstones. The time for formation of these paleosols was on the order of several thousands of years, considering the destruction of bedding in them and the fact that none show well-developed calcareous nodules.

En route

Some additional exposures of both the Mascall and Rattlesnake Formations can be observed in the hills to the west along U.S. Highway 26. Here, bluff and creek exposures of the Rattlesnake Formation have yielded the following fossil mammals (Merriam and others, 1925; MacFadden, 1984): Squirrel (*Spermophilus gidleyi*), single-toed horse (*Pliohippus spectans*), three-toed horses (*Cormohipparion occidentale* and *Hippotherium sinclairi*), rhinoceros (*Teleoceras* sp. cf. *T. fossiger*), peccaries (*Platygonus rex* and *Prosthennops* sp.), camel (Camelidae), bear (*Indarctos oregonensis*), and cat (Felidae).

Picture Gorge Basalt crops out 3.7 mi west of the junction of Highways 19 and 26 and includes a photogenic outcrop of columnar jointing. At a point 10 mi west of the junction, the road enters a narrow valley with exposures of lahars and flows of the Clarno Formation. As the road climbs up toward Keyes Summit, it passes upsection through Picture Gorge Basalt to Rattlesnake ash-flow tuff. Descending from Keyes Summit, the road passes down again through John Day Formation and then, in a number of large road cuts excavated in 1989, through magnificent series of volcanic breccias, plugs, and flows of the Clarno Formation.

Just west of Mitchell and north of the highway is Bailey Butte, a steeply-dipping andesite sill of the Clarno Formation. The sill intrudes the Hudspeth Formation, a middle Cretaceous (Albian to Cenomanian) marine shale. Ammonites (*Brewericeras hulensis* and *Leconteites lecontei*) can be found in calcareous nodules of the Hudspeth Formation a few miles north of here (Jones and others, 1965). The Hudspeth Formation interfingers with submarine fan conglomerates of the Gable Creek Formation in this area (Kleinhans and others, 1984).

Along U.S. Highway 26 and 3 mi west of Mitchell, look for a well-marked turnoff and take it north to the Painted Hills Unit of John Day Fossil Beds National Monument. At 2.4 mi north of Highway 26, the paved road to Painted Hills passes from Clarno Formation to the disconformably overlying John Day Formation, which includes an alkali olivine basalt 3.3 mi north of the highway.

The entrance to the Painted Hills Unit is southwest across Bridge Creek where the sealed road surface ends. Continue past the turnoff to the Visitors Center and into the colorful badlands, then turn south along a ridge to Lookout Point.

STOP 14. Painted Hills Overlook

From Lookout Point (SE¼NE¼ sec. 1, T. 11 S., R. 20 E., Painted Hills 7½-minute quadrangle) and several places on the way to it, spectacular outcrops of the color-banded, lower Oligocene Big Basin Member of the John Day Formation (Figure 8) are visible. The red bands are mainly subsurface (Bt) horizons of fossil soils of the kind formed under woodland (Alfisols). These interfinger with less developed, yellow fossil soils formed under open woodland and wooded grassland (Inceptisols) and also with fossil soils whose black subsurface horizons (iron manganese or placic horizons) formed in poorly drained parts of the landscape (gleyed Inceptisols).

Low on the hill 2 mi west of the lookout, numerous fossil plant remains have been collected at the type locality for assemblages called the "Bridge Creek Flora." This locality was discovered by Thomas Condon in 1865 (Clark, 1989) and subsequently studied in great detail by Ralph Chaney (Chaney, 1948) and Roland Brown (Brown, 1959). The fossil flora is generally similar to that examined in the John Day Formation behind the high school in Fossil (Stop 7). Wolfe (1981b) has estimated from foliar physiognomy of this flora that mean annual temperature was 11° to 12 °C, with a mean annual range of 22° to 24 °C.

The bluffs of John Day Formation to the north of the lookout are capped by the same extensive ash-flow tuff as seen at Sheep Rock (Stop 11). This tuff has been K-Ar dated near here at 25.9 m.y. (from Evernden and others, 1964, corrected by method of Dalrymple, 1979). Tuffs low in this bluff at a stratigraphic horizon 55 m above the base of the John Day Formation were dated at 31.9 m.y. (corrected from the same authors). Compared with outcrops of the stratigraphically equivalent Turtle Cove Member near Picture Gorge, few fossil mammals of the same kinds have been reported from here (T. Fremd, personal communication, 1991).

The brown badlands of the Kimberly Member and the white bluffs of the Haystack Member of the John Day Formation in the distance, under the long rampart of Columbia River basalt, have also yielded fossil mammals (of the late Arikareean and Hemingfordian land mammal "ages"). The lighter color, more calcareous composition, and less clayey texture of this part of the formation reflect less severe weathering in an increasingly dry climate. The middle Tertiary climatic deterioration of north-central Oregon is written prominently in paleosols of these scenic, color-banded badlands.

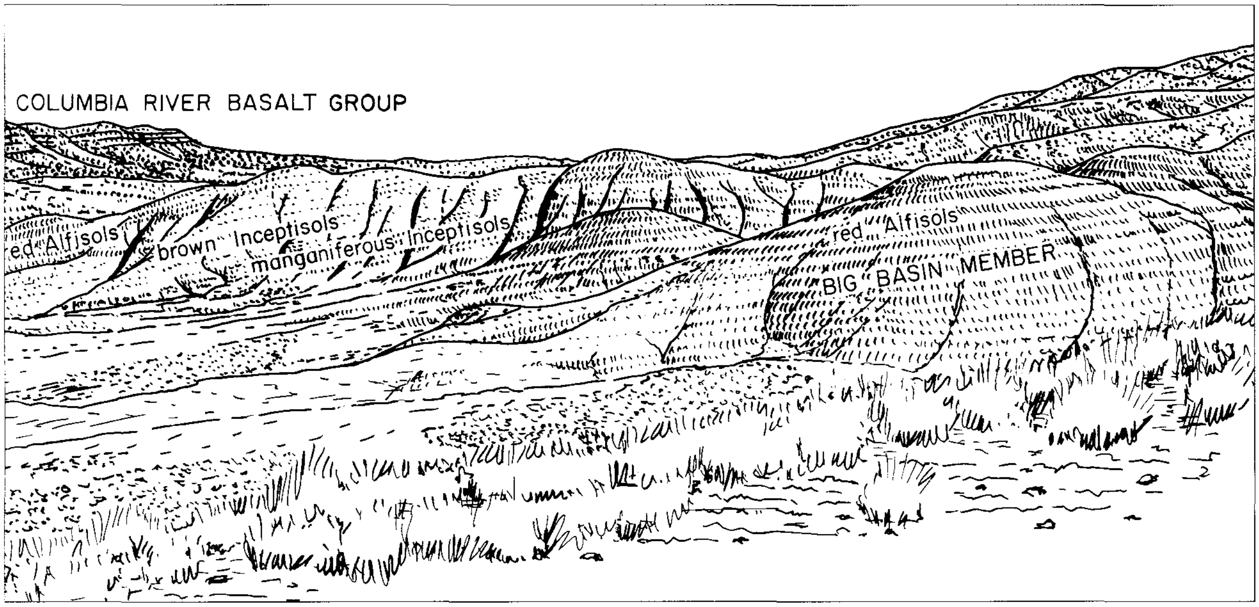

Figure 8. Geological sketch of the Painted Hills Unit of the John Day Fossil Beds National Monument, viewed from the west.

En route

Return south to U.S. Highway 26 and continue west toward Prineville. Ammonite-bearing Lower Cretaceous shales and sandstones of the Hudspeth Formation are exposed in road cuts low in the valley of Cherry Creek. These deposits of submarine fans are unconformably overlain by lacustrine and volcanic rocks of the Eocene Clarno Formation, which form the hills on either side of the road. The road cuts reveal more Clarno Formation as Highway 26 climbs toward Ochoco Summit.

STOP 15. Clarno lake beds, Ochoco Summit

Near the Ochoco National Forest boundary on the northeast side of Ochoco Summit, in a deep road cut on both sides of U.S. Highway 26 and 10 mi west of the Painted Hills turnoff (NW¼NW¼ sec. 17, T. 12 S., R. 20 E., Lawson Mountain 7½-minute quadrangle), occur black shales and gray, bedded sandstones of the Clarno Formation, intruded by a large sill of diabase containing veins of calcite, zeolites, and gabbro. The sill has uparched sediments in the central portion of the road cut, and there is a narrow chilled margin and zone of altered sediments. The sill is faulted against fluvial sandstones in the eastern portion of these road cuts.

The black shale is a deposit of a eutrophic lake. In an especially carbonaceous layer near road level are numerous scales and disarticulated skeletal debris of fish (Cavender, 1968), including remains of bowfins (cf. *Amia*), mooneyes (cf. *Hiodon*), catfish (aff. *Ictalurus*), and suckers (cf. *Amyzon*). These were large subtropical fish.

Overlying the lake deposits are alluvial sandstones and siltstones, in places with well-preserved fossil leaves, including viburnum (*Viburnum eocenicum*), cordia (*Cordia oregona*), and wingnut (*Pterocarya mixta*; all identified by the author). This fossil plant assemblage is similar to the late Eocene Goshen floras of the Willamette Valley (Chaney and Sanborn, 1933), from a time predating the Oligocene climatic deterioration and subsequent divergence in vegetation of western and eastern Oregon (Wolfe, 1981a). Paleosols in these alluvial deposits are limited to weakly developed profiles (Psamments) with fossil root traces and abundant relict bedding: an indication that these plants formed early successional vegetation of streamsides, again like the Goshen flora.

En route

Continue west over Ochoco Summit on U.S. Highway 26. Exposures of the Clarno Formation are poor in the drainage of Marks Creek. Past Ochoco Reservoir near Prineville, exposures of the basal ash-flow tuff of the John Day Formation occur. Closer to Prineville, the Rattlesnake ash-flow tuff forms a conspicuous ledge high on the hillsides. The rimrock on the skyline to the east and north of Prineville is the Madras flow of the Deschutes Formation. Prineville itself is built on Pleistocene lacustrine shales that were deposited when the Crooked River was dammed by intracanyon flows. These flows are well exposed in the gorge of the Deschutes River north of Redmond.

From Prineville, the road north toward Madras climbs between uplifted rocks of the John Day and Clarno Formations in Grizzly Butte to the east and Gray Butte to the west. The plateau over which the road approaches Madras provides excellent views on the skyline of Pliocene-Pleistocene volcanoes of the Cascade Crest: from the south, the Three Sisters, Mount Washington, Three Fingered Jack, and Mount Jefferson.

Return to Madras to conclude the second day of the field trip.

ACKNOWLEDGMENTS

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STORE NAMING CONTEST

ENTER THIS CONTEST TO NAME THE NATURAL RESOURCE AND OUTDOOR INFORMATION CENTER AND STORE OPENING FEBRUARY 1992 IN THE NEW STATE OFFICE BUILDING IN PORTLAND!
WIN A PIECE OF OREGON SUNSTONE JEWELRY!

What is this new facility? The State of Oregon Department of Geology and Mineral Industries will open a natural resource and outdoor information center and store on the ground floor of the new state office building in Portland, making available Department publications, materials from other state and federal natural resource agencies, U.S. Geological Survey topographic maps, and outdoor and interpretive types of literature from other sources. It will also provide computer access to natural resource and recreation data bases and serve as an Earth Science Information Center (ESIC) for the U.S. Geological Survey.

We need a short, wonderful name that will tell people exactly what our center and store is.

To enter the contest, send all entries in writing to Beverly F. Vogt, Oregon Department of Geology and Mineral Industries, 910 State Office Building, Portland, OR 97201. Five entries per letter or card will be accepted. Include name, address, and day phone number on each entry. Anyone is eligible, except for judges and their families.

Deadline is July 31, 1991, and all entries must be received by midnight of that date. Ties among entries will be broken on the basis of date received.

Judging of entries will be by a panel from natural resource agencies. Winners will be announced on August 24.

Prize will be a piece of Oregon Sunstone jewelry, a 40-percent discount on all purchases in the store for one year, and lots of publicity.

Questions? Call Beverly Vogt or Rhonda Moore at the Oregon Department of Geology and Mineral Industries, 229-5580.

Geothermal exploration in Oregon, 1990

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

INTRODUCTION

Geothermal exploration activity decreased in 1990 relative to 1989. Only one hole was completed, and the amount of leased federal land and lease revenues continued to decline. The total amount of federal land leased for geothermal resources has declined steadily since the peak in 1983.

DRILLING ACTIVITY AND RESULTS

Figure 1 shows the number of geothermal wells drilled and geothermal drilling permits issued from 1970 to 1990. Figure 2 shows the same information for geothermal prospect wells (depths <610 m). Table 1 lists the Oregon Department of Geology and Mineral Industries (DOGAMI) permits for geothermal drilling that were active in 1990. Six new permits were issued, all for geothermal wells. Drilling activity occurred on three holes, but only one was completed. California Energy Company (CEC) did some initial drilling on two locations in the volcanic highlands west of Bend. DOGAMI, working on a site near Santiam Pass, diamond-cored to 928 m on a hole rotary drilled in 1989 to 141 m.

One permit for geothermal prospect drilling was active: Permit 100, Anadarko Petroleum Corporation well 25-22A, Pueblo Valley area, Harney County. The well was suspended during 1990.

LEASING

The amount of leased federal land and lease revenues, while still decreasing, stopped the steep slide that has occurred in previous years, changing by only a few percent from 1989 to 1990 (Table 2; Figures 3 and 4).

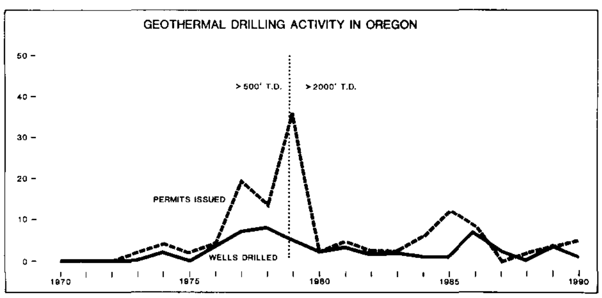

Figure 1. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 610 m.

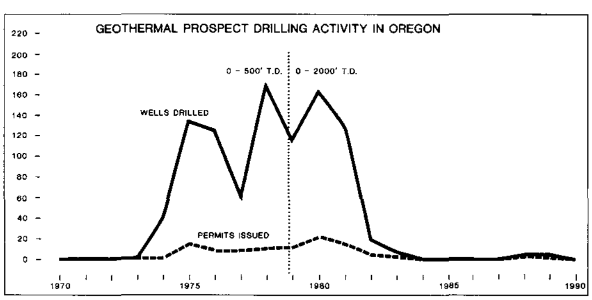

Figure 2. Geothermal prospect well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth of less than 610 m.

Table 1. *Active permits for geothermal drilling in 1990*

Permit no.	Operator, well, API number	Location	Status, proposed total depth (m)
116	Calif. Energy Co. MZI-11A (deepening) 36-035-90014-80	SW¼ sec. 10 T. 31 S., R. 7½ E. Klamath County	Suspended; confidential.
117	Calif. Energy Co. MZII-1 (deepening) 36-035-90015-80	SE¼ sec. 13 T. 32 S., R. 6 E. Klamath County	Suspended; confidential.
118	GEO-Newberry N-1 36-017-90013	SW¼ sec. 25 T. 22 S., R. 12 E. Deschutes County	Suspended; 1,387.
125	GEO-Newberry N-2 36-017-90018	SW¼ sec. 29 T. 21 S., R. 12 E. Deschutes County	Suspended; confidential.
126	GEO-Newberry N-3 36-017-90019	NE¼ sec. 24 T. 20 S., R. 12 E. Deschutes County	Suspended; 1,219.
131	GEO-Newberry N-4 36-017-90023	NE¼ sec. 35 T. 21 S., R. 13 E. Deschutes County	Suspended; confidential.
132	GEO-Newberry N-5 36-017-90024	NE¼ sec. 8 T. 22 S., R. 12 E. Deschutes County	Suspended; confidential.
138	GEO-Newberry NC54-5 36-017-90030	NE¼ sec. 5 T. 22 S., R. 12 E. Deschutes County	Canceled.
139	Oxbow Power Corp. 77-24 36-031-90001	SE¼ sec. 24 T. 13 S., R. 7½ E. Jefferson County	Suspended; 928.
140	Calif. Energy Co. MZI-9 36-035-90017	SW¼ sec. 9 T. 31 S., R. 7½ E. Klamath County	Canceled.
143	Calif. Energy Co. CE-BH-4 36-017-90031	SW¼ sec. 27 T. 16 S., R. 9 E. Deschutes County	Abandoned; confidential.
144	Anadarko Petroleum 52-22A 36-025-90004	NE¼ sec.22 T. 37 S., R. 33 E. Harney County	Permitted; 762.
145	Anadarko Petroleum 66-22A 36-025-90005	SE¼ sec. 22 T. 37 S., R. 33 E. Harney County	Permitted; 762.
146	Calif. Energy Co. MZI-1 36-035-90020	NW¼ sec. 3 T. 30 S., R. 6 E. Klamath County	Permitted; 1,676.
147	Calif. Energy Co. CE-BH-7 36-017-90032	NW¼ sec. 20 T. 17 S., R. 10 E. Deschutes County	Suspended; confidential.
148	Anadarko Petroleum 25-22A 36-025-90006	SW¼ sec. 22 T. 37 S., R. 33 E. Harney County	Permitted; 762.
149	Calif. Energy Co. CE-BH-5 36-017-90033	NW¼ sec. 25 T. 16 S., R. 9 E. Deschutes County	Permitted; 1,676.

KNOWN GEOTHERMAL RESOURCE AREA (KGRA) SALES

No KGRA lands were offered for bid in 1990. Some KGRA lands at Newberry volcano have been incorporated into a geological monument (see section on regulatory actions).

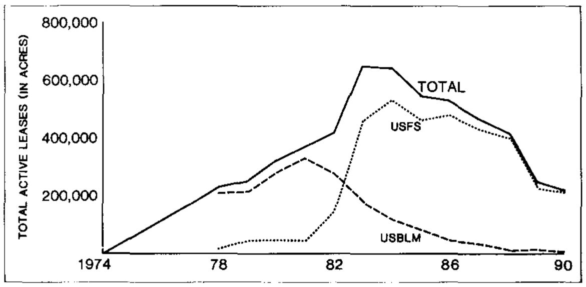

Figure 3. Active geothermal leases on federal lands in Oregon from the inception of leasing in 1974 through December 1990.

REGULATORY ACTIONS

Public Law 101-522, enacted November 5, 1990, created the Newberry Volcanoes National Monument. The monument area, combined with buffer zones of restricted access, encompasses about 85 percent of the land classified by the Federal Government as Known Geothermal Resource Area.

Anadarko Petroleum Corporation applied for permits to drill two new test wells near Borax Lake in the Alvord Desert area. Drilling is stalled pending review of appeals filed by various environmental organizations concerned about potential threats to the Borax Lake chub. In a related action, U.S. Representative Bob Smith introduced a bill to create an 812,870-acre Steens Mountain National Conservation Area. The bill failed to make it through Congress.

The Oregon Water Resources Department (WRD) wrote and amended administrative rules that addressed several geothermal issues pursuant to new legislation. The rules defined terms such as "thermal interference" or "substantial thermal alteration" and specified 65 °F as "a temperature below which low-temperature geothermal appropriations shall not be protected from thermal interference caused by ground-water appropriations for other purposes." Other provisions included injection well location, pump testing, and water analysis requirements.

WRD assisted in resolving a thermal-interference dispute near Vale. Two commercial users of low-temperature geothermal water reached a private agreement which avoided regulation by WRD.

DIRECT-USE PROJECTS

The direct use of relatively low-temperature geothermal fluids continued in 1990 at about the same level as over the last several years. Most of the activity is centered in Klamath Falls and Vale.

Ashland

Jackson Hot Springs in Ashland, Oregon, is still being run as a resort.

Klamath Falls

The Klamath Falls district heating system is back on line after replacement of defective pipe connections. Nearly all of the water from the system is being reinjected.

La Grande

The Hot Lake Recreational Vehicle Resort is utilizing 85 °C water from the Hot Lake artesian well to heat a pool and building. The company hopes to use the resource eventually to heat a fish-farming operation and to generate electricity.

Lakeview

In Lakeview, the binary-cycle electrical generating station set up several years ago remains idle. The 300-kilowatt (kw) unit had an output of 250 kw from 105 °C water in a test performed November 18, 1982 (Geo-Heat Center Quarterly Bulletin, 1982).

Paisley

The Paisley area has one of the best quality but least utilized low-temperature geothermal resources in the State. Thermal wells there reportedly have high flow rates (observations of Gerald L. Black, 1981) and temperatures as high as 111 °C at only 228 m (Oregon Department of Geology and Mineral Industries, 1982). A campground and recreational vehicle park utilizes hot water for a pool, but no other uses are known.

Vale

In Vale, the Oregon Trail Mushroom Company, which commenced full-scale operations in 1986, continues to operate using water from a 107 °C aquifer for heating and cooling. Oregon Trail annually produces 2.3 million kilograms of mushrooms, which are marketed in Spokane, Seattle, Salt Lake City, and the Treasure Valley Area in Idaho (Geo-Heat Center Quarterly Bulletin, 1987). Other users at Vale include Ag-Dryers (a grain-drying facility) and a greenhouse operation.

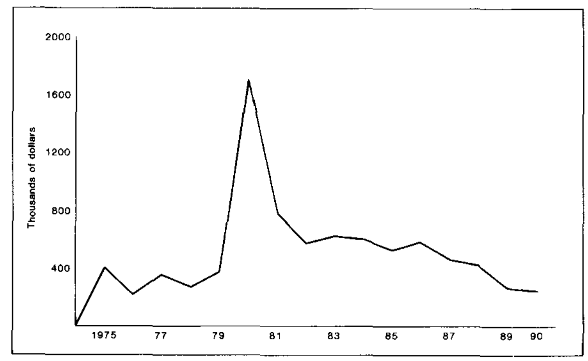

Figure 4. Federal income from geothermal leases in Oregon from the inception of leasing in 1974 through December 1990.

USGS ACTIVITIES

The U.S. Geological Survey (USGS) continued its Cascade Range research of igneous processes, hydrothermally altered rock, thermal waters, hydrothermal systems, and regional geology. Charles Bacon's work was focused on the compilation of a preliminary geologic map of Mount Mazama at 1:24,000 scale (Bacon, 1990a). His other activities included electron microprobe analysis of minerals in postcaldera lavas and their xenoliths (Bacon and others, 1990), a study of pre-Mazama rhyodacite lavas that are exposed around (clockwise) the northeast to south edges of Mount Mazama, a study of volcanic rocks from the flanks of Mount Mazama (Bacon, 1990b), and the completion of rock chemistry for samples collected from the deep caldera walls with the submersible craft *Deep Rover*.

Keith Bargar and Terry Keith studied hydrothermal alteration in seven geothermal core holes drilled by GEO-Newberry Crater, Inc., and Santa Fe Geothermal, Inc., on the outer flanks of Newberry volcano (Bargar and others, 1990). The core from drill holes on the northern (GEO-N3), eastern (GEO-N4), southern (GEO-N1), and southwestern (GEO-N5) flank encountered temperatures below 100 °C and is only slightly altered. Measured temperatures in drill holes GEO-N2, SFNC 72-03, and SFNC-01 on the west flank of the volcano are as high as 170 °C, and the drill core is moderately altered. Fluid inclusion studies of core from the west flank drill holes and the two intracaldera drill holes USGS-N2 and RDO-1 indicate that past temperatures were above 300 °C near the western caldera ring fracture and at the bottom of USGS-N2. Fluid inclusion homogenization temperatures also are hotter at shallower depths in RDO-1, the intracaldera drill hole closest to the southern ring fracture. Bargar and Keith also continued their preparation of a draft report on hydrothermal alteration in the Mount Hood area. Steve Ingebritsen completed a summary paper on hydrothermal systems of the Cascade Range in north-central Oregon (Ingebritsen and others, in preparation).

By means of potassium-argon dating, Leda Beth Pickthorn continues to define the age of many previously undated volcanic units. Perhaps most intriguing is the evidence that most of the Dalles Formation was emplaced about 8-7 Ma; consequently, the Dalles Formation is substantially younger than the 14-11 Ma Rhododendron Formation, with which it was once correlated. Eleven new K-Ar age determinations from the Klamath Falls area indicate that almost all volcanic units once presumed to be Quaternary are in fact Pliocene and Miocene in age (Pickthorn and Sherrod, 1990).

Work continued at Mount Hood by both Water Resources and Geologic Division personnel. William Scott, Jim Vallance, and Tim Pierson concentrated on mapping and stratigraphic studies mainly of latest Pleistocene and Holocene pyroclastic-flow and debris-flow deposits in the Sandy River and its headwater tributaries. Bob Tilling began petrologic studies by collecting a suite of samples from numerous Mount Hood and pre-Mount Hood units. Dave Sherrod mapped much of the Dog River and Badger Lake quadrangles in order to better understand the Hood River fault and its relation to Mount Hood.

Cynthia Gardner and Andrei Sarna-Wojcicki (both USGS) have undertaken a cooperative study with Brittain Hill (Oregon State University) and Rob Negrini (California State University, Bakersfield) to bolster correlations of distal tephra and near-vent, middle Pleistocene pyroclastic deposits in the Bend area. The Bend pyroclastic deposits, which include air-fall and ash-flow tuffs such as the Bend Pumice, Desert Springs Tuff, and Tumalo Tuff, are presumably correlative with ash beds in some lake sediments from northern California, northern Nevada, and southern Oregon. The team is using paleomagnetic and geochemical techniques to strengthen the correlations, which will lead to a better understanding of the age of all these deposits.

BONNEVILLE POWER ADMINISTRATION

In its 1990 Resource Program, the Bonneville Power Administration (BPA) offered to purchase, in joint ventures with regional utilities, 10 megawatts (MW) of output from each of three geothermal pilot projects in the Northwest. The main goal is to initiate development at three sites with potential for large-scale power production. Informal discussions with developers are underway, with letters of intent due September 3, 1991. Formal negotiations will begin on October 1, 1991.

To identify land use, environmental, and other issues associated with development and to provide a basis for informed resolution of these issues, several supporting activities are underway. It should be noted that although many of these activities focus on specific areas, they do not necessarily predict the locations of pilot projects.

The Oregon Department of Energy (ODOE) is performing studies to estimate the economic impact of a 100-MW geothermal project in Deschutes and Harney Counties. The Washington State Energy Office (WSEO) is doing similar studies for Skamania and Whatcom Counties. ODOE is also collecting data related to the operational and environmental records of existing U.S. geothermal plants.

Table 2. *Geothermal leases in Oregon in 1990*

Types of leases	Numbers	Acres
Federal leases in effect:		
Noncompetitive, USFS	142	220,536.08
Noncompetitive, USBLM	2	942.79
KGRA, USFS	1	100.00
KGRA, USBLM	7	16,465.12
Total leases issued:		
Noncompetitive, USFS	358	686,064.05
Noncompetitive, USBLM	266	406,157.79
KGRA, USFS	8	11,924.61
KGRA, USBLM	62	118,307.85
Total leases relinquished:		
Noncompetitive, USFS	216	465,527.97
Noncompetitive, USBLM	264	405,215.00
KGRA, USFS	7	11,824.61
KGR, USBLM	55	101,842.73
Lease applications pending	121	—

The Deschutes National Forest, ODOE, and BPA are working together on a study to assess the land use impact of geothermal development in the Bend highlands area south of Sisters. The two federal agencies are also jointly funding a wide range of public-information and involvement activities related to geothermal development.

BPA is cooperatively funding designs of environmental baseline monitoring programs for several areas. The USGS Water Resources Division expects to begin collecting data this summer for a hydrologic network at Newberry volcano and the Alvord Desert. Design work will begin this year for programs to monitor air quality, flora, fauna, seismicity, and subsidence at Newberry.

The Geothermal Resources Council has received a grant to produce a report on environmental issues in geothermal development. The report will give authoritative nontechnical background on geothermal energy development and production. A document of this sort has long been needed to help answer the "most often asked" questions about geothermal energy.

Under a BPA contract, the WSEO will complete a series of guides to the regulatory process for renewable resources. The agency will also conduct a workshop on geothermal concerns for utilities and overseeing agencies.

The Electric Power Research Institute (EPRI), which receives funding from BPA, has produced guidebooks on "Geothermal Power Plant Selection" and on "Sampling and Analysis of Geothermal Fluids." BPA and EPRI are jointly funding efforts by the University of Hawaii to reduce resource confirmation costs. Project completion is expected in late 1991.

DOGAMI APPLIED RESEARCH

The Oregon Department of Geology and Mineral Industries (DOGAMI) formulated a scientific drilling program in 1987 (Priest and others, 1987). Funding to support the program was found in 1989 from contributions of $200,000 by the U.S. Department of Energy (USDOE) and $100,000 by Oxbow Power Corporation (OPC). A hole was rotary drilled, and casing was set to 141 m in 1989 near Santiam Pass (Figures 5 and 6). In 1990, the hole was diamond cored to about 928 m, and geologic and geophysical data were collected.

Analysis of geophysical and geologic data from this hole will help toward a better understanding of geologic history and regional heat flow near the axis of active Cascade volcanism. The temperature-depth profile for the hole (Figure 7) is irregular with a high (120 °C/km) gradient in the lowermost part. Interpretation

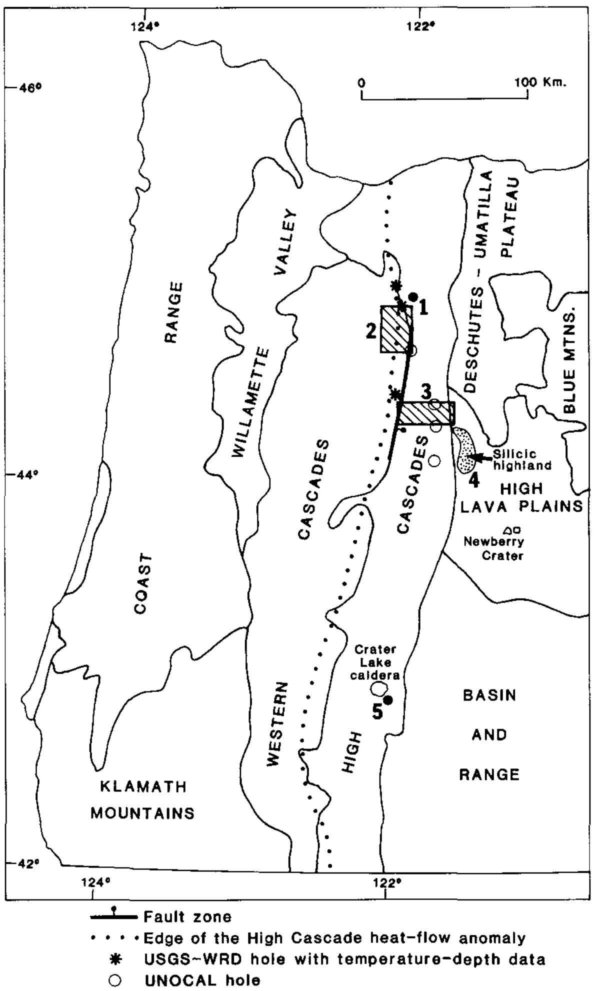

Figure 5. Physiographic provinces of western Oregon (after Dicken, 1950), showing major areas of geothermal activity discussed in text. 1. Location of Thermal Power drill hole CTGH-1. 2. Breitenbush study area. 3. Santiam Pass study area. 4. Silicic highland study area. 5. Location of CEC drill hole MZI-11A. Edge of High Cascade heat-flow anomaly after Black and others (1983).

of these data is still in an early stage, so no firm conclusions can be drawn.

George Priest and Brittain Hill of DOGAMI managed the project. Drilling engineering and contracting was conducted by W. Richard Benoit of OPC. OPC also retains ownership and regulatory responsibility for the drill hole. David D. Blackwell of Southern Methodist University conducted all geophysical logging of the hole and is analyzing the results, including determination of deep heat flow in the area (Figures 8 and 9).

Those interested in conducting scientific studies of the drill hole or samples are encouraged to contact this author for further information. The hole will be accessible for experiments in the early summer of 1991 but will be plugged and abandoned thereafter. Drill core and cuttings from the hole are stored at Oregon State University (OSU) in Corvallis. Contact Brittain E. Hill, Department of Geosciences, Oregon State University, Corvallis, OR 97331-5506 (phone 503-737-1201) for access to cores and cuttings.

Core from four temperature-gradient holes was donated to DOGAMI by UNOCAL in 1988 and is currently available for use in research projects. The holes, drilled in the central High Cascades (Figure 5, open circles), reached depths ranging from 250 to 610 m. No temperature data are publicly available from the holes, but detailed lithologic logs of the diamond core have been produced as part of DOGAMI's scientific drilling program.

GEO-HEAT CENTER, OIT

The Geo-Heat Center at the Oregon Institute of Technology (OIT) in Klamath Falls specializes in assisting in the development of low-(<90 °C) and moderate-temperature (90°-150 °C) geothermal applications for direct use. The Center is under contract with USDOE to provide a limited amount (based on merit) of free technical and economic analysis services to private developers, engineering consultants, and public agencies throughout the U.S. The assistance can range from answering technical questions and simple consultation on methods, materials, equipment, and applications to troubleshooting problems in existing systems. The Center maintains a geothermal library of over 4,000 volumes, which is open to lay and technical readers; publishes a quarterly Bulletin with domestic and foreign authors and a "Geothermal Direct Use Engineering and Design Guidebook" of more than 400 pages; and is involved in applied research on direct applications.

The Center continues to be involved in the evaluation and monitoring of the Klamath Falls aquifer, and the staff plays an active role on the Klamath Falls Geothermal Advisory Committee.

ACTIVITIES OF OREGON WATER RESOURCES DEPARTMENT

The Oregon Water Resources Department low-temperature geothermal program evaluated numerous proposals to inject spent geothermal effluent. This activity was largely the result of a City of Klamath Falls ordinance that now requires such injection within the city. Processing of these proposals is a coordinated effort with the Oregon Department of Environmental Quality and is required for a permit from that agency. By year's end, proposals from eighteen institutional, commercial, and domestic users were being processed in Klamath Falls. Injection rates under these proposals range from 2 to 450 gpm. In addition, an institution near Bend has submitted a proposal to inject 1,500 gpm.

WRD also regulates extraction of low-temperature (65°-256 °F) geothermal resources. Regulatory activities are summarized in the section on regulatory actions.

ACTIVITIES OF OREGON DEPARTMENT OF ENERGY

In 1990, ODOE performed research on geothermal development issues for outside organizations and provided assistance to the public. Research included both ongoing joint research with the Washington State Energy Office (WSEO) and new work for the Bonneville Power Administration (BPA). Technical assistance includes tax credit reviews for public and agency clients.

In 1990, geothermal research with WSEO was limited to digital mapping of a representative prospect area (Mount Mazama). This work covered several 7½-minute topographic quadrangles and included transportation, topography, and well-location layers. This work was part of a regional effort to create renewable-energy site maps for the northwestern states. Only one site was digitized in 1990, but the goal is to expand the effort to include all renewable-energy sites in all northwestern states.

BPA initiated research to estimate local economic impacts of a 100-MW geothermal power plant project. These impact estimates are being done for hypothetical projects in Deschutes and Harney Counties, Oregon. Further research for BPA (to be completed in 1991) will include land use impact estimates and the assembling of a database of existing U.S. geothermal power plants.

The geothermal specialist of ODOE also participated in teaching a course on geothermal energy sponsored by Central Oregon Community College and, as a contribution to the annual Geothermal Resources Council meeting, published a paper on the Northwest market for geothermal power in the 1990's.

ODOE continues to certify geothermal tax credits for both homes and businesses in the state. The ODOE geothermal staff reviewed 80 residential tax credit applications in 1990. A total of 94 residential systems received final certification. The total number of geothermal residential tax credits issued from 1978 through 1990 is 690.

ODOE responds to inquiries on geothermal energy development from the public and answered 119 such inquiries in 1990. The agency has received an average of about 125 inquiries annually since 1984.

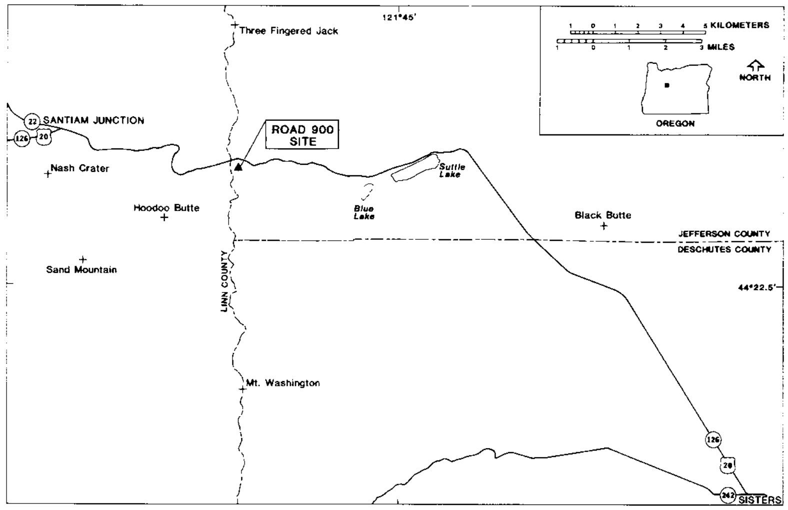

Figure 6. Location of scientific drill site near Santiam Pass, Oregon.

RESEARCH BY OSU

Brittain E. Hill, a doctoral candidate at Oregon State University (OSU), is continuing his work on Quaternary ash flows in the Bend area (Hill, 1985) and the silicic highland west of Bend. He is also the field supervisor for scientific work on the scientific drill hole at Santiam Pass.

Jack Dymond and Robert Collier of the OSU College of Oceanography continued their investigation at Crater Lake National Park. Their objective is to determine whether or not geothermal input exists on the floor of the lake. Data collected in 1989 from a surface ship and a submarine were analyzed and summarized in a draft final report to the National Park Service. The report is still being reviewed but is expected to be finished in 1991.

RESEARCH BY WASHINGTON STATE UNIVERSITY

Richard Conrey is finishing up a four-year doctoral study of the Mount Jefferson area. He found that, for the last 2.5 Ma, about 200 km^2 of the area has been the site of andesitic to rhyodacitic volcanism (Conrey, 1988). He postulates that a granodiorite-tonalite batholith lies at shallow depths beneath the area.

MOUNT MAZAMA AREA (CRATER LAKE AREA)

The reader is referred to Black and Priest (1988) and Priest (1990) for a detailed history of geothermal development issues at Mount Mazama. No new exploration activity occurred in 1990.

The National Park Service is continuing the previously mentioned research by Jack Dymond and Robert Collier of OSU).

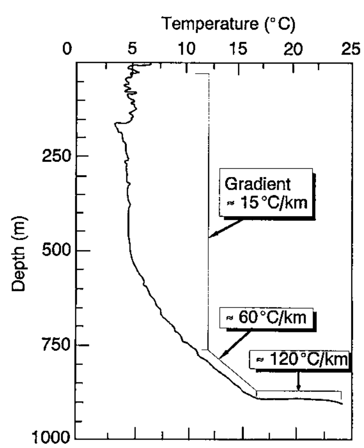

Figure 7. Temperature-depth data from Santiam Pass drill hole 77-24, thirty days after the end of drilling. Note the rapid increase of temperature near the bottom.

ACKNOWLEDGMENTS

We acknowledge the cooperation of numerous individuals in government and industry. Jacki Clark of the U.S. Bureau of Land Management (BLM) provided the federal leasing data. Jack Feuer of BLM provided much useful information on regulatory issues. Dennis Olmstead and Dan Wermiel of DOGAMI furnished the data on drilling permits. George Darr of BPA, Alex Sifford of ODOE, and Donn Miller of WRD provided information on their agencies' activities for the year. Gene Culver of OIT provided information on OIT activities and the status of direct use projects around the state. David Sherrod of USGS supplied an account of USGS activities in Oregon. Jack Dymond of Oregon State University provided information on his study of Crater Lake.

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Figure 8. Drill rig used for diamond coring at the Santiam Pass scientific drilling project. Rig was operated by the Tonto Drilling Company and is capable of drilling to 1.2 km. Drilling from 141 m to 928 m took 35 days starting August 14, 1990.

Figure 9. W. Richard (Dick) Benoit (left) of Oxbow Power Corporation, who conducted drilling engineering and contracting, and David D. Blackwell (right) of Southern Methodist University at the site of the Santiam Pass scientific drilling project.

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USGS completes 7½-minute quadrangle map series for Oregon

The culmination of a 42-year mapping effort in Oregon was celebrated on May 21, 1991, at the annual spring meeting of the State Map Advisory Council (SMAC) in Salem. A special ceremony attended by federal, state, and local government representatives marked the completion of first-time, 7½-minute topographic mapping for Oregon by the U.S. Geological Survey (USGS).

Roy Mullen, acting chief of the USGS National Mapping Division praised the State of Oregon for its cooperation in the project. He presented to Oregon Secretary of State Phil Keisling a commemorative certificate signed by U.S. Secretary of the Interior Manuel Lujan and prepared on a reproduction of the first Oregon topographic map published by the USGS, the 1893 map of the Ashland 1° by 1° quadrangle in Jackson County. He also presented a framed copy of the Drewsey quadrangle in Harney County, the final quadrangle map of the 7½-minute series.

In the now-complete series, Oregon's 96,981 square miles are covered on 1,944 separate map sheets at the scale of 1:24,000 (1 inch on the map equals about 2,000 feet on the ground). This is the most detailed map series published by the USGS. Each map covers 7½ minutes of latitude by 7½ minutes of longitude, which in Oregon represents an area of 52 to 55 square miles.

The ceremony at the meeting of SMAC also underlined the role of the Council in the mapping effort. SMAC is directed by executive order of the governor to coordinate and foster cooperative mapping efforts in Oregon. In 1979, under chairmanship of Deputy State Geologist John D. Beaulieu of the Oregon Department of Geology and Mineral Industries (DOGAMI), SMAC declared that statewide completion of the 7½-minute series was its top priority. With only 41 percent of the state completed in this series at that time, a plan was formulated to finish the entire state by the late 1980's. Elements of the plan included (1) a specific eight-year schedule with yearly monitoring of progress, (2) involvement of the Oregon congressional delegation to urge priority status for Oregon, (3) recruitment of a State Resident Cartographer to promote cooperative activities, and (4) adoption of a modified publication format—provisional maps, which are less refined graphically but more expeditiously completed.

The USGS began producing 7½-minute maps of Oregon in 1949 to replace the earlier 15-minute maps (scale 1:62,500) as the most detailed topographic maps. Other topographic map series by the USGS include the 1:100,000-scale and 1:250,000-scale series, state base maps at 1:500,000 and 1:1,000,000 scale, and national park maps. All these maps are available from the USGS and over the counter at DOGAMI offices.

The USGS effort will now focus on two further needs of the 7½-minute series. One is revising and updating the maps to keep pace with our rapidly changing landscape; the other is the conversion of these paper maps into digital (computer-stored) form to increase their utility. The USGS is building the National Digital Cartographic Data Base to provide a wide range of map data in computer-compatible form. As quadrangle map data are converted to digital form, production of new and custom maps and revision of these maps is greatly assisted. Furthermore, the availability of digital geographic data will enable wider use of geographic information systems to aid resource management, area analysis, and planning activities. *—Adapted from USGS news release*

Cavansite and pentagonite from Lake Owyhee State Park, Malheur County, Oregon*

by Jon Gladwell, 3235 SE 56th, Portland, Oregon 97206-2007, (503) 771-4123

The two dimorphous calcium vanadium silicates cavansite and pentagonite are known to occur in a road cut at Lake Owyhee State Park , Malheur County, Oregon. State Park regulations prohibit mineral collecting on park land; however, the author; Mike Sunde; Alex, Karen, and Bonnie Huang; and Scott Sanderson were granted permission for limited collecting at the location during early 1990.

The locality is within the right-of-way of the Malheur County road that provides access to the state park and points south. Both the State and the County, in turn, lease the land from the U.S. Bureau of Reclamation. Therefore, it was necessary to secure approval from all three entities, and the Bureau of Reclamation coordinated the permit process. The result was a series of three collecting expeditions, which together yielded somewhat less than one thousand small specimens of cavansite and five specimens of pentagonite.

The deposit occurs in the south bank of the road cut, just northeast of the day-use area of the park. It is the last road cut before the road descends into the day-use area. Apparently, the deposit had not been heavily worked since road construction in the late 1950's, and so a considerable amount of weathered overburden and debris had to be removed before good material was exposed. The host rock, a palagonite tuff, is spongy in nature and is difficult to break cleanly. In most cases, hand-collecting techniques caused the matrix to peel apart into conchoidal sections resembling onionskin. As a result, most specimens show much matrix and only a little mineralization. From an aesthetic perspective, the most desirable specimens (and, of course, the least common) are the compact, tightly packed rosettes that we describe as "blueberries." Less tightly packed specimens, which tend to lie flatter, as well as those covered by secondary mineralization occur most frequently and are a much paler blue in comparison. In many cases, the cavansite is partially to completely covered with associated drusy heulandite, analcime, or calcite, which produces the paler color but adds sparkle.

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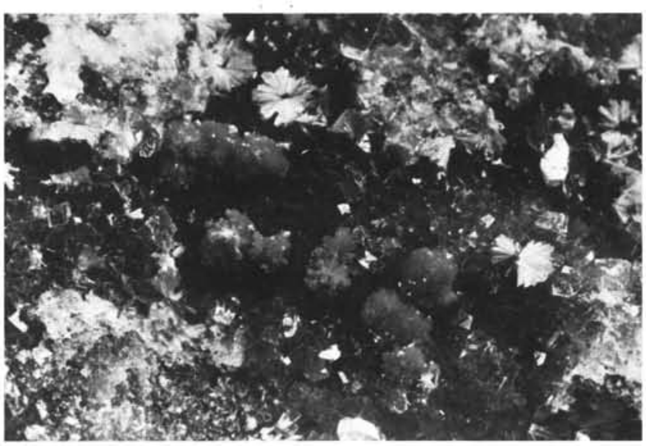
The pentagonite specimens were found in one small fracture that ran perpendicular to the main trend of the cavansite. Only five small pieces were recovered and were, in fact, identified only after the material had been brought home and examined closely.

The cavansite and pentagonite occur as sky-blue to greenish-blue, radiating prismatic rosettes up to 5 mm in diameter in isolated to packed groupings along small, narrow fractures in the palagonite lapilli tuff. The host rock is part of the Sucker Creek Formation (Corcoran, 1965), whose palagonite tuffs and breccias weather to form the brown and tan badland slopes on the east side of the park. Basalt and basaltic andesite flows of the Owyhee Basalt (Bryan, 1929) form the prominent, overlying, dark cliff faces. New geologic investigations of the Lake Owyhee region (Rytuba and others, 1990) indicate that both the palagonite tuffs and the overlying basalts were erupted and deposited in complex, fault-bounded basins developed during middle Miocene time. Many of the popular chalcedony, agate, and picture-rock deposits in the Lake Owyhee area were formed, along with calcite and calcite-zeolite vein systems, as the basins developed. Interestingly enough, many of these chalcedony and picture-rock occurrences are now under evaluation for hot-spring-type gold deposits.

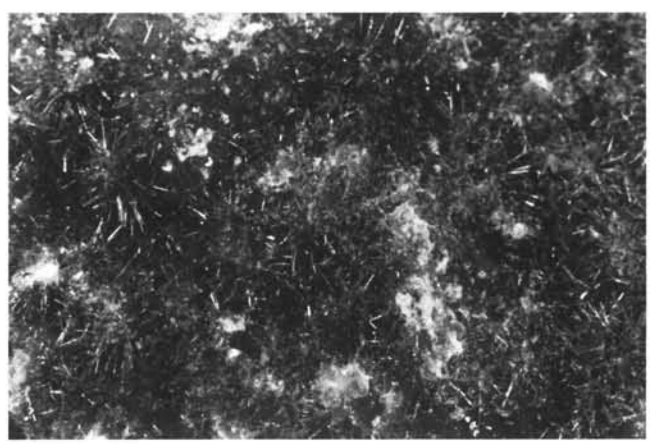
At this deposit, abundant colorless analcime, stilbite, chabazite, thomsonite, and heulandite, as well as colorless to pale-yellow calcite and rare green apophyllitye, are associated with the cavansite and pentagonite. The Lake Owyhee occurrence and a similar emplacement (of cavansite only) near Goble, Columbia County, Oregon (both co-type localities) are the only known deposits of these two minerals in the United States.

Minor localized faulting along the road cut has permitted the secondary mineralization in the interstitial spaces, which are typically less than 2 mm in width. In the hand specimens examined, it appears that the associated minerals were deposited contemporaneously with the cavansite and pentagonite. Many specimens occur with a portion of the cavansite covered by associates, while within a centimeter one will find a beautiful blueberry perched upon calcite or one of the zeolites.

The 1961 discovery of these two minerals at Lake Owyhee is attributed to Mr. and Mrs. Leslie Perrigo of Fruitland, Idaho. Later on, in 1963, Dr. John Cowles of Rainier, Oregon, discovered the Goble occurrence. Cavansite and pentagonite were first de-



Cavansite, heulandite, and calcite from Owyhee State Park, Malheur County. Field of view is approximately 24 mm.



Pentagonite from Owyhee State Park, Malheur County. Field of view is approximately 24 mm.

scribed in 1973 (Staples and others, 1973). These investigators used X-ray fluorescence and crystal-structure analysis to determine that cavansite ($Ca[VO]Si_4O_{10}\cdot 4H_2O$) is orthorhombic, conforms to space group Pcmn (D_{2h}^{16}), has a unit cell with a=10.298(4), b=13.999(7), and c=9.601(2) angstroms, contains four formula units, and is optically biaxially positive and strongly pleochroic. Pentagonite, the dimorph, occurs as prismatic crystals twinned to form fivelings with a star-shaped cross section. Also orthorhombic, it belongs to space group $Ccm2_1$ (C_{2v}^{12}) and has a unit cell with a=10.298(4), b=13.99(7), and c=8.891(2) angstroms, contains four formula units, and is biaxially negative. The cell dimensions given for these two species vary slightly, presumably because of varying zeolitic water content. Both cavansite and pentagonite have layer structures in which the individual layers are held together by VO^{2+} groups and Ca^{2+} ions, but they differ in the way the SiO_4 tetrahedra link to form the layers.

The collecting group intends to provide a representative specimen of cavansite free of charge to academic institutions (including primary and secondary schools) who may wish to add this species to their permanent collections. Interested educators should address requests to the author. Small specimens of cavansite will be provided upon request to interested collectors who inquire in person at Lake Owyhee State Park, but no mail inquiries will be honored. In addition, collectors who are unable to visit the park may obtain a small study specimen of cavansite by sending a check for $5.00, to cover packing and shipping costs, to the author at the address above. Additional specimens will not be available for purchase.

The collecting group gratefully acknowledges the efforts of the following individuals who worked together to arrange the permits and make the collecting trips possible: Jerold D. Gregg (Project Superintendent), James Brooks (Director of Lands), Brent Carter (District Geologist), Curtis Carney (Facility Manager), all from the Bureau of Reclamation, Central Snake Projects Office; Dan Rau (Park Ranger), State of Oregon; and Mark Ferns (District Geologist) and Jerry Gray (Economic Geologist), Oregon Department of Geology and Mineral Industries. The author also especially acknowledges the expert technical assistance of Mark Ferns. This effort stands as an example of successful cooperation between the private collecting fraternity and the local, state, and federal regulatory agencies.

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Cascade Range volcanoes are just dormant

(This brief introduction to the volcanism of the southern Cascade Range is an adaptation of a recent release from the Grants Pass field office of the Oregon Department of Geology and Mineral Industries.)

The year 1990 marked the 10th anniversary of the eruption of Mount St. Helens (1980) and the 75th anniversary of the eruption of Mount Lassen (1915). We also know of relatively "recent" eruptions of other dormant Cascade Range volcanoes: Mount Hood in 1865, 1859, and the late 1700's; Mount Shasta in 1786; the Three Sisters area in A.D. 800, A.D. 400, and 0-300 B.C.; Newberry Volcano in A.D. 700; and the Crater Lake volcanic complex (Mount Mazama) in 2000 B.C. and 5600 B.C. Eruptions of Mount McLoughlin in southern Oregon have dates between one million years and ten thousand years, but several undated lava flows on the mountain are suspected by scientists to be younger than that. The history written by these and thousands of other eruptions is the history of the formation of the Cascade Range.

Volcanoes in the Cascade Range occur in a band that parallels the Pacific Coast. This orientation is not accidental: it is related to the boundary between the Pacific Ocean and and the North American continent, the line where two moving pieces of the Earth's crust meet. Low-density continental crust that forms North America is creeping westward (about as fast as a fingernail grows) and riding over dense oceanic crust that forms the floor of the Pacific Ocean. The oceanic crust is heated as it sinks deep beneath the continent and eventually melts. The resulting lava rises to the surface at Cascade Range volcanoes. Volcanoes are not found in the Coast Range because the oceanic crust below is not yet deep enough or hot enough to cause melting of the rock.

Geologists of the U.S. Geological Survey (USGS) estimate that over the past 730,000 years the Cascade Range in southern Oregon alone (south of Eugene) has erupted an average of 1.3 million cubic yards of lava (enough to bury an area of 100 acres under an 8-foot-thick layer of lava)—per year. This estimate is conservative: it does not, for instance, consider that some lavas are erupted and deposited in the form of low-density pumice, which can mean a five-fold expansion in volume. The estimate is also an average amount, which means that in individual eruptions volcanoes tend to produce much larger amounts of lava in comparatively short periods that may be separated by tens, hundreds, or thousands of quiet years. Mount St. Helens discharged about 500 times the average amount in just a few minutes during the 1980 eruption.

When an eruption occurs, the hazards accompanying it vary with the type of eruption, the drainage patterns of the area, and the prevailing wind. Volcanic flows, landslides, avalanches, and high-density gases may follow stream valleys and gullies for miles, leaving them only when propelled by their own momentum. Volcanic ash from explosive eruptions is blown downwind. With winds blowing predominantly to the east or southeast, the eruptions of Mount Mazama (Crater Lake) and Mount St. Helens both produced thick ash deposits in those directions. Flooding is another major concern during eruptions. Floods occur when runoff from rapidly melting snowpack and glaciers breaches unstable temporary dams created by mudflows, logjams, landslides, or avalanches.

For an estimate of the frequency of eruptions and, on that basis, projections for future eruptions, Mount Shasta is probably better studied than any other volcano in the area. USGS volcanologists report that Shasta has erupted 10 or 11 times in the last 3,400 years and at least three times in the last 750 years and that the last eruption was in 1786. Assuming that the volcano's behavior has not changed, they give, for any given decade, odds of one in 25 to one in 30 that Mount Shasta will erupt again.

Geologists learned a great deal about the behavior of Cascade Range volcanoes by monitoring Mount St. Helens. Scientists hope that the relationship they observed between lava movement, vent activity, shallow earthquakes, and eruptions at Mount St. Helens will be representative of Cascade Range volcanism in general and that eruptions of other volcanoes in the Cascades can be predicted in a similar manner. □

Welded tuffs of the Winberry Creek area, central Oregon Cascade Range

by Gary L. Millhollen, Department of Earth Sciences, Fort Hays State University, Hays, Kansas 67601

INTRODUCTION

Densely welded tuffs are present in the North Fork Winberry Creek drainage east of Fall Creek Reservoir in Lane County, Oregon (Figure 1). Western Cascade volcanic rocks are dominantly volcaniclastic in this area, although some lavas also are present (Millhollen, 1989).

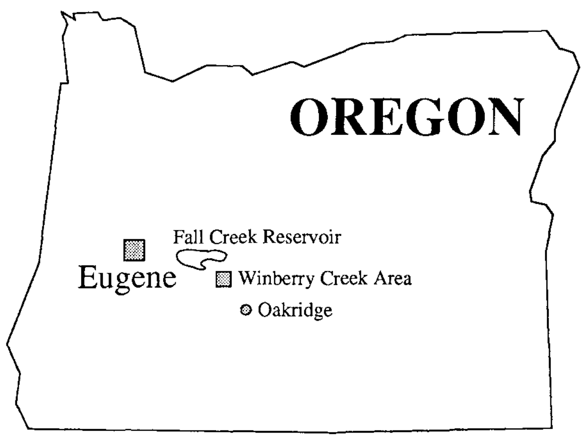

Figure 1. Sketch map showing location of Winberry Creek area.

The welded tuffs described here occur in road cuts along the North Fork of Winberry Creek (samples 1 and 2, Table 1) and on the slopes of Winberry Mountain (samples 3-5, Table 1). The first two analyzed samples are from the same road cut in a black, glassy zone that is about 4 m thick (see explanation, Table 1). Ash-flow zoning patterns (Smith, 1960) are difficult to determine in these exposures because of alteration in the more porous rocks, but less densely welded zones, including zones with devitrified glass shards, are also apparent in the road cuts of the first three samples in Table 1. Sherrod and Smith (1989) described widespread alteration of glass and other unstable materials in pyroclastic-flow deposits older than 10 Ma (million years before the present) in the Oregon Cascade Range as being very low-grade metamorphic recrystallization. Because the densely welded tuffs show little alteration or metamorphism, this process must be controlled by access of water in more permeable rocks.

The ash flows that produced these welded tuffs probably were of relatively small volume, given the limited extent of the densely welded zones in existing exposures. If they were of small volume, they probably were erupted from vents relatively near these exposures because of the requirement of sufficient heat for dense welding.

The five analyzed samples resemble black obsidian in hand specimen, but in thin section (Figure 2) they show distinctive eutaxitic texture characterized by flattened and deformed glass shards, as described by Ross and Smith (1961). The glass is pale brown to colorless and is mostly isotropic. All five samples contain abundant plagioclase phenocrysts, opaque grains (Fe-Ti oxides), and minor lithic fragments, but the nature of the pyroxene phenocrysts in sample 3 (Table 1) is different from that in the other samples. Sample 3 contains similar amounts of clinopyroxene and orthopyroxene, whereas the other four samples contain dominantly clinopyroxene plus a partly altered mineral that probably is a ferroan orthopyroxene (ferrosilite, according to the nomenclature of Morimoto, 1988). Clinopyroxene grains in all samples are pale-green augite. Peck and others (1964) described the pyroxenes in the welded tuff at the locality of the first two samples here as being ferroaugite (now Fe-rich augite) and less abundant eulite (now ferrosilite).

Table 1. *Chemical analyses and CIPW norms of welded tuffs*

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Major elements (weight percent)					
SiO_2	67.70	67.85	68.27	69.01	69.01
TiO_2	1.79	1.52	0.65	0.37	0.29
Al_2O_3	13.45	13.36	13.24	13.44	13.10
Fe_2O_3	0.69	1.23	0.15	0.35	0.85
FeO	3.27	2.58	3.75	3.57	2.70
MnO	0.13	0.13	0.12	0.15	0.12
MgO	0.19	0.14	0.82	0.22	0.14
CaO	1.93	1.63	1.75	1.94	1.72
Na_2O	5.02	4.32	3.57	4.00	4.00
K_2O	2.23	2.64	2.58	3.07	3.64
P_2O5	0.04	0.04	0.16	0.04	0.04
H_2O^+	3.09	3.21	3.03	3.93	3.51
H_2O^-	0.89	1.02	1.61	0.67	0.56
Total	100.42	99.67	99.70	100.79	99.68
Trace elements (ppm)					
Li	5.5	7.4	9.2	11	12
Cr	346	111	327	126	158
Ni	15	6.5	18	11	11
Cu	334	165	236	144	208
Zn	220	161	174	157	176
Rb	71	82	50	69	77
Sr	154	120	177	156	119
Ba	725	665	740	700	740
CIPW norms (weight percent)					
Q	25.71	29.72	32.00	28.00	27.69
Or	13.66	16.35	16.04	18.87	22.50
Ab	44.05	38.30	31.78	35.20	35.40
An	7.86	8.20	8.03	9.74	7.36
Di	1.56	—	—	—	1.13
Hy	2.50	1.89	8.37	6.74	3.95
Mt	1.04	1.87	0.23	0.53	1.29
Il	3.52	3.02	1.30	0.73	0.58
Ap	0.10	0.10	0.40	0.10	0.10
C	—	0.55	1.87	0.11	—

Explanation: Co <5 ppm in all samples. All are black, vitrophyric, densely welded tuffs.

Sample 1. From upper middle part of black vitrophyre in road cut on Forest Service Road 1802 along North Fork Winberry Creek; same location as analysis 15 of Peck and others (1964), p. 45; middle part of sec. 20, T. 19 S., R. 2 E.; sample 80M019.

Sample 2. From about 10 cm below the top of the black vitrophyre; same location as 1 above; sample 80M020.

Sample 3. From road cut on Forest Service Road 188 (Lowell Ranger District map); NW¼ sec. 28, T. 19 S., R. 2 E.; sample 80M096.

Sample 4. From road cut on Forest Service Road 188; NE¼ sec. 28, T. 19 S., R. 2 E.; sample 81M094.

Sample 5. From large boulder on track of Forest Service Road 188; near west-central edge of sec. 27, T. 19 S., R. 2 E.; sample 81M106.

Analyses by Christine McBirney, AA Laboratory, Department of Geological Sciences, University of Oregon, Eugene.

Figure 2. Photomicrograph of densely welded tuff along the North Fork Winberry Creek (sample 1, Table 1, plane-polarized light. Eutaxitic texture is defined by flattened and deformed glass shards. Two clinopyroxene grains are near center of photo; the one containing opaque grains is about 0.3 mm in long dimension. Three large plagioclase grains are near edges of photo.

AGE RELATIONS

The age of the first sample in Table 1 was determined by whole-rock K-Ar methods to be 21.6 Ma (Millhollen, 1989). This corresponds to the early Western Cascade volcanic episode of Priest and others (1983) or to Oregon Cascade Range time unit T_3 of Sherrod and Smith (1989).

Relative age relations are difficult to determine in this area because of (1) limited rock exposures due to thick soils and dense vegetation and (2) the effects of eruption onto an existing topography that was probably irregular, with flows tending to follow topographic lows. The three welded tuff samples for which ages are not available (samples 3-5, Table 1) are from somewhat higher elevations across North Fork Winberry Creek from the dated welded tuff (samples 1 and 2, Table 1), implying somewhat younger ages. However, although dips are very gentle and variable in this area, a dip of about 8° could account for the difference in elevation. Because of petrographic similarities and close association in the field and because of chemical similarities described below, samples 4 and 5 (Table 1) are believed to be from the same welded ash flow, whereas sample 3 is probably from a different ash flow.

A dacite from a quarry along South Fork Winberry Creek at an elevation roughly midway between those of the dated welded tuff and the other welded tuffs has an age of 16.6 Ma (Millhollen, 1989). This age corresponds to the early part of the late Western Cascade volcanic episode of Priest and others (1983) or of time unit T_2 of Sherrod and Smith (1989). Because of the uncertainties in relative age relations, the two apparently younger ash flows should be regarded as being of either late early Western Cascade or early late Western Cascade age.

CHEMICAL COMPOSITIONS AND MAGMA EVOLUTION

All five of the analyzed samples are densely welded, vitrophyric tuffs of rhyolitic composition, according to the IUGS chemical classification scheme (Le Maitre, 1984). Some chemical differences among the analyses (Table 1) are believed to reflect the fact that the five samples are from three different ash flows. For example, TiO_2 contents are highest in samples 1 and 2, intermediate in 3, and low in 4 and 5; these differences are also apparent when the analyses are normalized to 100 percent volatile-free.

All samples are hydrated (Table 1), but they are not oxidized, and they show only incipient alteration or metamorphism in thin section. The percentages of TiO_2 and other elements that are essentially immobile during hydration might change if other constituents are added to or subtracted from the rock, but the ratio of two immobile elements would be unaffected by the hydration process. Of the major elements, TiO_2 and Al_2O_3 are most likely to be immobile, so that any differences in Al_2O_3/TiO_2 ratios should reflect magmatic compositional differences. Since all five samples have similar Al_2O_3 contents (Table 1 and normalized "dry" values), the different TiO_2 contents are reflected in different Al_2O_3/TiO_2 ratios (Figure 3), with samples 1 and 2 having low ratios, 3 intermediate, and 4 and 5 high ratios. Like Al_2O_3, SiO_2 contents are similar for all five samples (Table 1 and normalized values), so SiO_2/Al_2O_3 ratios are similar for all samples (Figure 3). However, some SiO_2 may be lost during hydration of glass (several studies summarized by Fisher and Schmincke, 1984).

Figure 4 shows some other chemical differences to support the hypothesis that the samples are from three different ash flows. Samples 1 and 2 and samples 4 and 5 plot as separate pairs, while sample 3 plots away from the others. Since K and Rb show similar magmatic geochemical behavior, the K/Rb ratio should reflect the parent magma and source rock compositions plus any effects of assimilation or magma mixing; fractionation of plagioclase should have had little effect on this ratio. The Ti/Rb ratio, however, is a ratio of a high field strength (HFS) element to a low field strength, or large ion lithophile (LIL), element. This ratio may also reflect differences in parent magma and source rock compositions, as well as assimilation and magma mixing, but it may also be affected significantly by fractionation of clinopyroxene and especially Fe-Ti oxide. A possible weakness of this plot is that K and Rb contents may change during hydration of glass, although Zielinski and others (1977) found no significant change in Rb contents due to hydration of rhyolitic glasses.

The CIPW norm (Table 1) shows that sample 3 is distinctly peraluminous (normative corundum). Comparison of the norms of samples 1 and 2 indicates that this welded tuff probably is metaluminous (normative diopside in 1 exceeds normative corundum in 2). Similarly, the welded tuff of samples 4 and 5 also

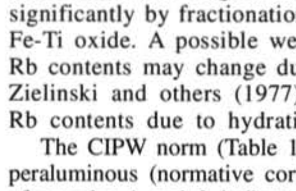

Figure 3. Major-element ratios of SiO_2/Al_2O_3 - Al_2O_3/TiO_2. Open boxes are samples 1 and 2, filled triangle is sample 3, filled circles are samples 4 and 5 of Table 1.

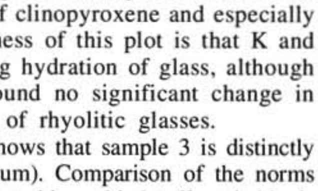

Figure 4. Ppm ratios of Ti/Rb - K/Rb. Open boxes are samples 1 and 2, filled triangle is sample 3, and filled circles are samples 4 and 5 of Table 1.

probably is metaluminous. However, norms also may be affected by chemical changes during hydration.

Since the welded tuffs contain minor lithic fragments, these might contribute somewhat to chemical differences observed. Also, eruption from a chemically zoned magma chamber can produce chemical variation in a single ignimbrite (e.g., Hildreth, 1981). The ash flows of the welded tuffs studied here probably were of too small a volume to show chemical variation. However, the petrographic similarity among samples 1, 2, 4, and 5 suggests the possibility that these welded tuffs may be from the same ash flow, with sample 3 being from a second ash flow.

Although existing data are inadequate for accurate modeling of the evolution of these magmas, simple major-element mass-balance mixing calculations were used to test the hypothesis that these silicic magmas may have been derived from more mafic magmas mainly by fractional crystallization of clinopyroxene, orthopyroxene, plagioclase, and Fe-Ti oxide, phases that are present in the welded tuffs and in lavas in this area (Millhollen, 1989). Initial calculations used compositions of these lavas (from Millhollen, 1989) and compositions of the above mineral types from island arc gabbros in Alaska (DeBari and Coleman, 1989). The gabbroic minerals were chosen to represent arc magma chamber minerals. Subsequent calculations added ideal quartz (SiO_2) and K-feldspar ($KAlSi_3O_8$) to include possible effects of assimilation of these minerals.

Table 2 shows the results of calculations using an early Western Cascade basaltic andesite from the Winberry Creek area (53.5 percent SiO_2 normalized volatile-free; number 2 in Table 1 of Millhollen, 1989) as the parent magma composition for all calculations. The calculations used the least-squares method to minimize the sum of the squares of the residuals (R-sq in Table 2). Values of R-sq less that 1 are considered reasonable and less than 0.3 a good fit. For each sample calculation as presented in Table 2, the sum of fractionated minerals minus the sum of assimilated minerals equals 100 percent.

Because of the simple approach used, too much emphasis should not be placed on the numbers shown in Table 2. However, the results are consistent with the hypothesis that fractional crystallization was the dominant process of magma evolution, with assimilation playing a lesser and variable role. Plagioclase is the dominant fractionating mineral, which is consistent with its abundance as a phenocryst mineral in rocks in this area. Pyroxenes, especially clinopyroxene, are also important fractionating minerals in these calculations. The presence of plagioclase and pyroxene phenocrysts in the rocks and the absence of hornblende and biotite suggest that fractionation occurred in shallow crustal magma chambers.

Possible sources of error in these calculations include inappropriate mineral compositions, especially due to changing solid-solution compositions during magma evolution, and the effects of magma mixing. But since these rocks are silicic, magma mixing probably was not a major process, at least in the later stages of evolution that produced rhyolitic magmas. Basaltic rocks of the early Western Cascades in this area also contain altered groundmass (Millhollen, 1989), which is another possible source of error for calculations using compositions of these rocks as parent magmas. The immediate parent magma probably was of intermediate composition and may have evolved by a combination of processes, such as the MASH hypothesis of Hildreth and Moorbath (1988).

Table 2. *Results of mass-balance calculations*

Sample	Plag	Cpx	Opx	Mt	Il	Qtz	Kf	R-sq
1	68.7	17.7	13.8	3.8	1.5	-4.7	-0.8	0.92
2	71.9	20.6	14.1	4.0	1.5	-8.8	-3.4	0.62
3	78.7	26.8	12.6	4.3	2.7	-18.2	-6.8	0.20
4	75.0	21.2	15.1	3.3	2.9	-11.5	-6.0	0.50
5	75.5	19.7	15.4	3.4	2.9	-9.7	-7.3	0.56

Explanations: Sample numbers are the same as in Table 1. Positive values indicate fractionation; negative values indicate assimilation. Values are expressed as percentages. Plag=plagioclase, Cpx=clinopyroxene, Opx=orthopyroxene, Mt=magnetite, Il=ilmenite, Qtz=quartz, Kf=K-feldspar, R-sq=sum of the squares of the residuals. See text for further explanation.

CONCLUSIONS

Three ash flows that were erupted in the vicinity of what is now Winberry Mountain and North Fork Winberry Creek during the later part of the early Western Cascade volcanic episode of Priest and others (1983)—and possibly during the early part of the late Western Cascade episode—formed densely welded, vitrophyric zones. The rhyolitic magmas that produced these ash flows probably evolved from more mafic magmas mainly by fractional crystallization of plagioclase, clinopyroxene, orthopyroxene, and Fe-Ti oxide in shallow crustal magma chambers. Assimilation of crustal materials also contributed to magma evolution. Magma mixing may have affected magma compositions in early stages but probably was not important in later stages of magma evolution.

ACKNOWLEDGMENTS

I would like to thank Paul Hammond for his comments on densely welded tuffs, David Sherrod for a copy of his open-file report, and George Priest for his suggestions on improving the manuscript. The program GPP by D.J. Geist, B.H. Baker, and A.R. McBirney was used for the mass-balance calculations. This work has been supported in part by research grants from the Fort Hays State University Graduate School.

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MINERAL EXPLORATION ACTIVITY

MAJOR MINERAL-EXPLORATION ACTIVITY

County, date	Project name, company	Project location	Metal	Status
Baker 1991*	Cave Creek Nerco Exploration	T. 11, 12 S. R. 42 E.	Gold	App
Baker 1991	Gold Ridge Mine Golconda Resources	T. 12 S. R. 43 E.	Gold	Expl
Baker 1992*	Pole Creek Placer Dome U.S.	T. 13 S. R. 36 E.	Gold, silver	Expl
Crook 1988	Bear Creek Freeport McMoRan	Tps. 18, 19 S. R. 18 E.	Gold	Expl
Crook 1991	Bear Creek Project Coeur Explorations	T. 18 S. R. 18 E.	Gold	Expl
Grant 1990	Prairie Diggings Western Gold Explor.	T. 13 S. R. 32 E.	Gold	Veg
Grant 1992*	Standard Mine Bear Paw Mining	T. 12 S. R. 33 E.	Gold, copper	Expl
Harney 1990	Pine Creek Battle Mtn. Explor.	T. 20 S. R. 34 E.	Gold	Expl
Jefferson 1991	Red Jacket Bond Gold	Tps. 9, 10 S. R. 17 E.	Gold	App
Josephine 1990	Martha Property Cambiex USA, Inc.	T. 33 S. R. 5 W.	Gold	Expl
Lake 1988	Quartz Mountain Wavecrest Resources.	T. 37 S. R. 16 E.	Gold	Expl
Lake 1990	Glass Butte Galactic Services	Tps. 23, 24 S. R. 23 E.	Gold	Expl
Lane 1990	Grouse Mtn. Project Bond Gold Exploration	T. 23 S. Rs. 1, 2 E.	Gold	Expl
Lincoln 1991*	Iron Mtn. Quarry Oreg. St. Highw. Div.	T. 10 S. R. 11 W.	Basalt	App
Malheur 1988	Grassy Mountain Atlas Precious Metals	T. 22 S. R. 44 E.	Gold	Expl, com
Malheur 1988	Harper Basin Project Amer. Copper & Nickel	T. 21 S. R. 42 E.	Gold	Expl
Malheur 1988	Jessie Page Chevron Resources Co.	T. 25 S. R. 43 E.	Gold	Expl
Malheur 1988	Kerby Malheur Mining	T. 15 S. R. 45 E.	Gold	Expl, com
Malheur 1989	Hope Butte Chevron Resources Co.	T. 17 S. R. 43 E.	Gold	Expl, com
Malheur 1990	Ali/Alk Atlas Precious Metals	T. 17 S. R. 45 E.	Gold	Expl
Malheur 1990	Buck Gulch Teague Mineral Prod.	T. 23 S. R. 46 E.	Ben-tonite	Expl
Malheur 1990	Calavera NERCO Exploration	T. 21 S. R. 45 E.	Gold	Expl
Malheur 1990	Cow Valley Butte Cambiex USA, Inc.	T. 14 S. R. 40 E.	Gold	Expl
Malheur 1990	Freezeout Western Mining Corp.	T. 23 S. R. 42 E.	Gold	Expl
Malheur 1990	Goldfinger Site Noranda Exploration	T. 25 S. R. 45 E.	Gold	Expl
Malheur 1990	Grassy Mtn. Regional Atlas Precious Metals	T. 22 S. R. 44 E.	Gold	Expl
Malheur 1990	Katey Claims Asarco, Inc.	Tps. 24, 25 S. Rs. 44, 46 E.	Gold	Expl
Malheur 1990	KRB Placer Dome U.S.	T. 25 S. R. 43 E.	Gold	App

MAJOR MINERAL-EXPLORATION ACTIVITY (continued)

County, date	Project name, company	Project location	Metal	Status
Malheur 1990	Lava Project Battle Mtn. Explor.	T. 29 S. R. 45 E.	Gold	Expl
Malheur 1990	Mahogany Project Chevron Resources	T. 26 S. R. 46 E.	Gold	App
Malheur 1990	Racey Project Billiton Minerals USA	T. 13 S. R. 41 E.	Gold	Expl
Malheur 1990	Sand Hollow Noranda Exploration	T. 24 S. R. 43 E.	Gold	Expl
Malheur 1990	Stockade Mountain BHP-Utah Intl.	T. 26 S. Rs. 38, 39 E.	Gold	Expl
Malheur 1990	Stockade Project Phelps Dodge Mining	Tps. 25, 26 S. R. 38 E.	Gold	Expl
Malheur 1991*	Lucky G Sunshine Prec. Metals	T. 22 S. R. 44 E.	Gold	App
Malheur 1991	Rhinehardt Site Atlas Precious Metals	Tps. 18, 19 S. R. 45 E.	Gold	Expl
Malheur 1991*	Sagebrush Gulch Kennecott Exploration	Tps. 21, 22 S. R. 44	Gold	App
Malheur 1991*	Silver Claims Sunshine Prec. Metals	T. 23 S. R. 43 E.	Gold	App
Malheur 1991	White Mountain D.E. White Mtn. Mining	T. 18 S. R. 41 E.	Dia-toms	App
Malheur 1991*	Big Red Ron Johnson	T. 20 S. R. 44 E.	Gold	Expl
Marion 1990	Bornite Project Plexus Resources	T. 8 S. R. 3 E.	Copper	App com

Explanations: App=application being processed. Expl=Exploration permit issued. Veg=Vegetation permit. Com=Interagency coordinating committee formed, baseline data collection started. Date=Date application was received or permit issued. *=New site

Status changes

The number of permits issued continued to grow during the first year of the exploration-permit requirements program.

The new category of "Veg" is now shown in the status column for sites where all earth moving and seeding have been done, but the permit will not be released until revegetation is successful. During this final period of a permit, the fee and bond are reduced.

The application from Atlas Precious Metals for a permit to take a bulk sample from their Grassy Mountain project was determined to be incomplete. A revised application is expected.

A project-coordinating committee has been set up for the Bornite Project of Plexus Resources Corporation in Marion County.

Regulatory issues

Numerous bills relating to mining have been introduced into the legislative session. House Bill 2244, significantly modified by the Governor's Mine Work Group, a multi-interest-based committee, was passed by House and Senate in slightly differing versions. At press time, all amendments had been agreed to by the conference committee.

Hearings have been held by the Department of Environmental Quality on its proposed water quality regulations for large-scale mining operations. Comments made during the hearings will be reviewed before the rules are presented to the Environmental Quality commission for adoption.

Questions or comments should be directed to Gary Lynch or Allen Throop in the Mined Land Reclamation Office, 1534 Queen Avenue SE, Albany, OR 97321, telephone (503) 967-2039. □

MLR honors mining operators

In May, the Mined Land Reclamation (MLR) program of the Oregon Department of Geology and Mineral Industries presented several awards to mining operators for their exemplary efforts in conducting environmentally beneficial mining operations and reclamation programs.

Outstanding Operator Award

Awards for outstanding operator were given to Morse Brothers, Inc., for its Progress Quarry near Beaverton and to Bonnanza Mining, Inc., for its operation near Halfway. In both cases, the operators exceeded the requirements of their permits to provide excellent environmental protection in the day-to-day operation of the facilities.

Three other operators received an honorable mention: Howard DeYoung at Talent, Eagle Picher Mineral Industries at Vale, and S2F Corporation at Philomath.

Reclamation Award

The Reclamation Award went to LTM for its Kendall Bar project. Given to the operator whose completed reclamation exemplifies best the goals of the reclamation statutes of the State of Oregon, the award recognizes LTM's reclamation efforts for including raptor nest sites, islands, irregular shorelines, and fish structures (to enhance fish habitat), which added to the cost of the project but achieved a type of reclamation that blends exceptionally well with surrounding land use.

Bonnanza Mining, Inc., operation near Halfway, Baker County, showing the mining cut before backfilling. View is to the north, upstream along the Pine Creek channel hidden in the trees.

The same Bonnanza Mining operation area as in photo above, after completion of backfilling. View is to the south. Ponded area in background is a newly created artificial wetland area.

Morse Brothers, Inc., Progress Quarry operation near Beaverton, Washington County. Mined-out quarry area is being backfilled with about 600,000 yds of clean material for protection of ground water.

Honorable mention was awarded to O'Neill Sand and Gravel near Redmond for the O'Neill Junction site and to Beaver State Sand and Gravel of Roseburg for its Brosi pit.

Exploration Reclamation Award

This award, given to the exploration permittee whose completed reclamation exemplifies the goals of the reclamation requirement of the State, was given to Malheur Mining, Inc., for the reclamation accomplished at the company's Kerby project.

Horizon Gold Shares, Inc., received honorable mention for its reclamation at the Hope Butte exploration site.

Agency Reclamation Award

MLR also honors government agencies whose reclamation efforts exceed State of Oregon reclamation requirements. This year, the recognition was awarded to the Region 4 Office of the Oregon State Highway Division for reclaiming, during the award time period, six sites of which two were exempt from the reclamation requirement.

The Tualatin Fire District and Umatilla County received honorable mention in this category.

Good Neighbor Award

MLR's Good Neighbor Award for outstanding community service was given to Howard DeYoung of Talent for the exemplary community spirit he demonstrated. Besides completing excellent reclamation work at the company's Bear Creek site, Mr. DeYoung volunteered equipment and time to the community to accomplish reclamation tasks unrelated to his mining operation.

Small Miner Award

Two awards were given: The first went to Fred Smith and Sons of Brownsville, Linn County, who have been mining aggregate and completing concurrent reclamation since the early 1970's, creating fish and wildlife habitat in the mined areas without any obligation through bonding or formal reclamation requirements. The second award was given to the Eastern Oregon Mining Association, honoring seven of its members, Butch Bullard, John Lyons, George Spears, Lyle Chadwick, Max Buckner, Erv Lamb, and Tiny Malone, who, besides being independent operators, contributed their volunteer efforts in reclaiming a number of mining sites that had been abandoned by others. □

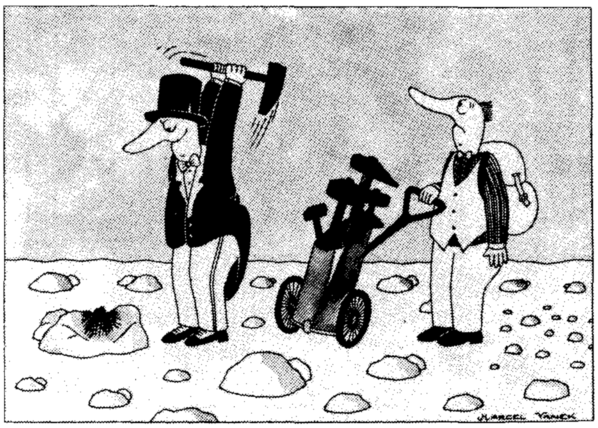
BOOK REVIEWS

Crystal Quest 1, by Marcel Vanek. Published 1991 by Geoscience Press, Inc., 1040 Hyland Circle, Prescott, AZ 86303. Four pages of introductory text by the artist, 89 pages of cartoons, $9.95.

Reviewed by John Eliot Allen, Emeritus Professor of Geology, Portland State University, Portland, Oregon 97207-0751

This little volume (8½ by 5½ inches) contains 76 one- or two-page cartoons, half of them in color. In his introduction, the artist describes the mineral collector's unflagging quest for true paradise. He illustrates it by showing how in the Garden of Eden the serpent offers to Adam and Eve—not the apple from the Tree of Knowledge but rock hammers.

The cover blurb states: "It is said that Marcel Vanek picked up his first rocks as a baby in Bratislava, Czechoslovakia, in 1964. Today, his vast mineral collection includes many fine specimens from classic Czechoslovakian localities—and three fossils. If you care to count, he claims to have painted 673 mineral species into his 199 mineralogical cartoons."



From Crystal Quest 1. *Used with permission of the publisher, Geoscience Press, Inc., Prescott, AZ. Copyright 1991 by Marcel Vanek.*

Vanek may have started out as a mineralogist, but now he is a cartoonist. His cartoons are in a typical central European style, consisting mostly of wordless, highly sardonic (no pun intended!), biting, and sometimes risqué comments on the human foibles of mineral collectors and fantastic encounters with the objects of their quest. Actually, Vanek reminds me more of Gary Larson than of any other U.S. cartoonist.

The cartoons were originally published in 1990 in Germany under a spoofy title that might be rendered as *Journal of Caricatural Mineralogy, Volume 1, Number 1.* The few words, mostly names, in the cartoons were left untranslated by the U.S. publisher, since they are easily understood—including even such exotic mineral names as "sexite"!

I am sure that some rock and mineral collectors will cringe when looking at some of Vanek's caustic visual comments. I am also sure that others will get many a chuckle. Some examples:

Dedication: Collector (hammer sticks out of his backpack) who is obviously agitated and concerned comes running to the end of the pier where a determined suicide candidate is just jumping off, carrying a large rock that is tied to his neck. That is panel one. In panel two, the collector is back on the pier, dripping wet but happily applying his hammer to the rock that still has the suicide candidate's rope tied around it. The cut-off end of the rope and the bubbles on the water next to the pier leave no doubt that here is a really dedicated collector!

Risks of the trade: Two collectors carrying G-picks like pistols in their belt holsters are facing each other, ready to "draw" for a high-noon "shootout" over possession of the giant amethyst geode that lies between them.

Nightmares: Collector in a cave breaks off a dripping stalactite (panel one), only to get washed out of the cave (panel two) by the torrent of water gushing out of the—hollow!—stalactite remnant in the cave ceiling.

Pleasant dreams: Metallic meteorites have a special "attraction" for this collector's clever, labor-saving device: He does not search for them or race after them as they fall (like some of his colleagues in the book)—he just stands by with a smile on his face while his giant horseshoe magnet catches one meteorite after the other.

But I should give away no more of these! You should get a copy and see for yourself.

Paleozoic and Early Mesozoic Paleogeographic Relations: Sierra Nevada, Klamath Mountains, and Related Terranes, ed. by D.S. Harwood and M.M. Miller. Published 1990 by Geological Society of America, Boulder, Colorado, as Special Paper 255, 422 p., softbound, $62.

Reviewed by Tom Wiley, Regional Geologist, Grants Pass Field Office, Oregon Department of Geology and Mineral Industries

The editors Harwood and Miller have collected 25 papers that emphasize Paleozoic and early Mesozoic terranes in northern California and their ties to the western margin of cratonal North America. The book is divided into five sections: (1) Early and middle Paleozoic magmatic-arc, basinal, and ophiolitic terranes; (2) middle and late Paleozoic marginal basin systems; (3) Carboniferous and Permian paleogeography of island-arc terranes; (4) Permian and Triassic arc sequences and accretionary complexes; and (5) early Mesozoic convergent-margin paleogeography. Each section contains three to seven papers. The editors also have taken the time to compile a 12-page index.

The volume and many of the individual papers represent commendable efforts to integrate geology, geophysics, geochemistry, and paleontology into workable paleogeographic reconstructions. Taken together, these papers make a powerful case for the origin and evolution of these terranes as an arc system, developed in part on continental crust or close enough to a continent to receive continental detritus.

An overview paper by C.M. Rubin, M.M. Miller, and G.M. Smith includes descriptions and interpretations of related terranes along the North American margin north to the Brooks Range. One paper, by J. Charvet and six coworkers, includes specific discussion of the Blue Mountains in northeastern Oregon.

Most authors point toward North America as the source of continental detritus and continental geochemical signatures in the arc terranes and suggest an origin in the eastern Pacific (eastern Panthalassa) adjacent to the continent. However, the paper by C.H. Stevens, T.E. Yancey, and R.A. Hanger presents paleontologic evidence for a significant geographic barrier (deep ocean) separating North America from the Eastern Klamath terrane during the Permian.

An occurrence of Eastern Klamath terrane rocks in the northern Sierra Nevada is described in a paper by A.S. Jayko. E.A. Mankinen and W.P. Irwin summarize late Paleozoic and Mesozoic paleomagnetic constraints on paleogeographic reconstructions. Several papers describe rocks in western Nevada, the constraints they place on the nature and timing of events along the continental margin, and the implications for outboard terranes.

The book is a worthwhile addition to the library of any geologist working in Paleozoic or early Mesozoic terranes of western North America. It is available from the Geological Society of America, P.O. Box 9140, Boulder, CO 80301, and may be ordered by phone 800-472-1988 or 303-447-2020 or FAX 303-447-1133. □

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