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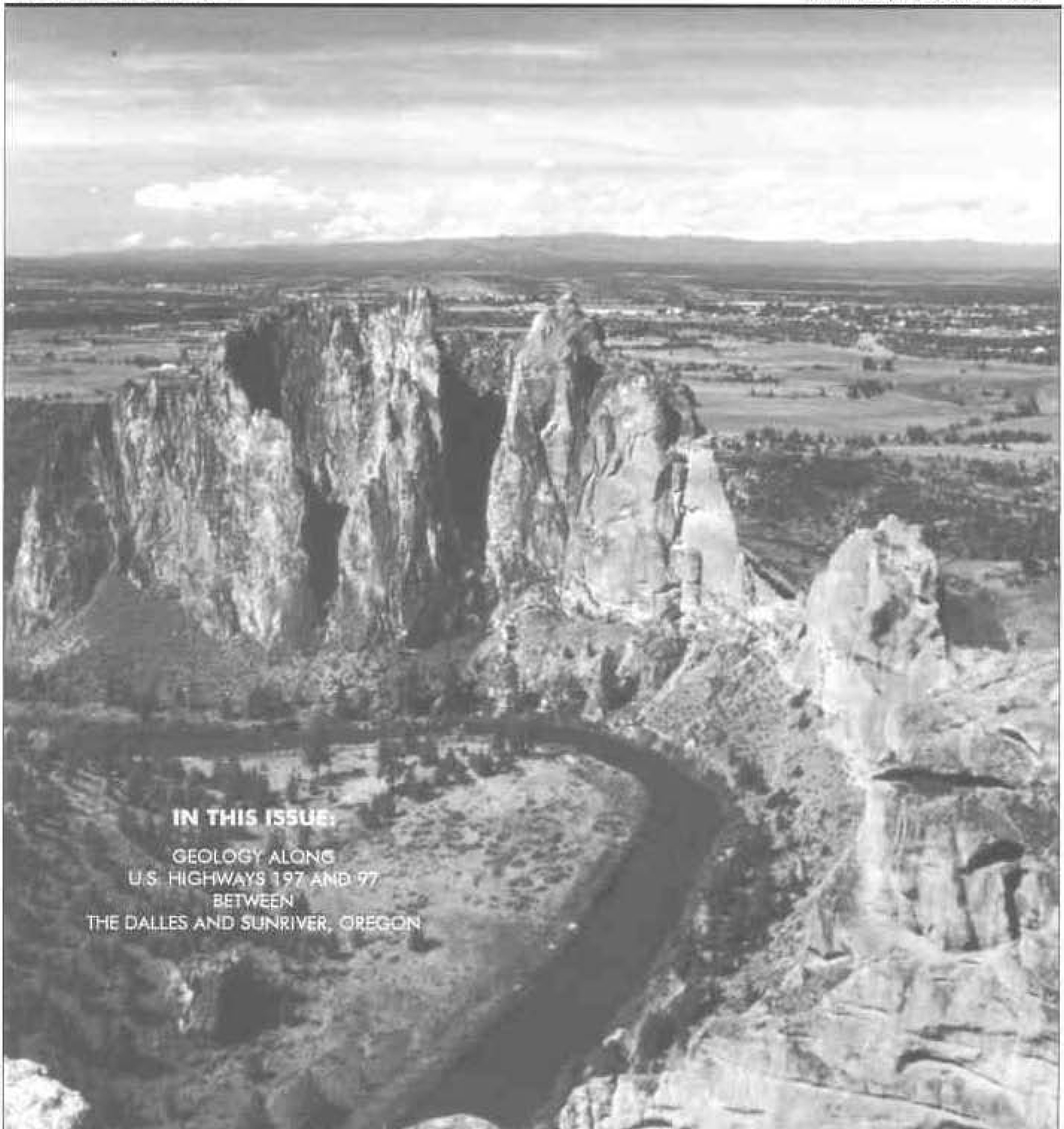

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Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted. If manuscript was prepared on common word-processing equipment, a file copy on diskette should be submitted in place of one paper copy (from Macintosh systems, high-density diskette only). Graphics should be camera ready; photographs should be black-and-white glossies. All figures should be clearly marked; figure captions should be together at the end of the text.

Style is generally that of U.S. Geological Survey publications. (See USGS Suggestions to Authors, 7th ed., 1991, or recent issues of *Oregon Geology*.) Bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Include names of reviewers in the acknowledgments.

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, letters, notices, and meeting announcements should be sent to Klaus Neuendorf, Editor, at the Portland office (address above).

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Cover photo

View to the southwest at Smith Rock State Park. Crooked River flows between basalt lava, on left, and indurated tuff forming Smith Rock. Quarried cinder cones mark the Tetherow Butte volcanoes beyond Terrebonne in the middle ground. Cascade volcanoes are visible on the skyline. Article on geologic tour guide from The Dalles to Sunriver begins on next page.

Barnett appointed to DOGAMI Governing Board

Arleen N. Barnett of Portland has been appointed by Governor John Kitzhaber and confirmed by the Oregon Senate for a four-year term beginning December 1, 1997, as Governing Board member of the Oregon Department of Geology and Mineral Industries (DOGAMI). Barnett succeeds John W. Stephens of Portland, who served two four-year terms on the Governing Board.

Arleen N. Barnett

Arleen Barnett is the Manager of the Human Resources Operations Department of Portland General Electric Company (PGE). She has been working with PGE since 1978, mostly in managing functions and predominantly in the area of Human Resources. She attended Pepperdine University and graduated from Abilene Christian University in Texas. She is married and has two teenaged children. She is on the Advisory Council of the Salvation Army Greenhouse and is active in the music ministry of her church.

In addition to Arleen Barnett, the three-member board includes Jacqueline G. Haggerty of Enterprise and Donald W. Christensen of Depoe Bay. □

Correction

The index to last year's volume of *Oregon Geology*, published on page 150 of the last (November/December 1997) issue, contains some errors for which we apologize.

If you wish to correct your copy of the index, please note the following:

Under "Field trip guides," the page references for the two entries should be reversed.

Under "Mined land reclamation," the same applies to the first and third entry.

Under "Tsunamis," the page references for "Center for Tsunami Inundation Mapping . . ." and "Hazard signs adopted . . ." also should be reversed. □

Geology along U.S. Highways 197 and 97 between The Dalles and Sunriver, Oregon

by Gary Smith, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

This highway-geology guide was prepared for an as-yet unpublished travel brochure for the general public. We thank the author for his permission to print it here and for his help in adapting it to a different format. —*Ed.*

Introduction

A LAND BUILT BY VOLCANIC ERUPTIONS

The west coast of North America is referred to as an active continental margin. Large-scale geological processes involving horizontal motions of the outermost layers of the earth cause earthquakes, volcanic eruptions, and the uplift of mountains. Volcanoes are responsible for the formation of most of the rocks formed in Oregon over the past 45 million years. The rocks and landscapes that one sees while driving between The Dalles and Sunriver are nearly all related, in one fashion or another, to volcanism.

TYPES OF VOLCANOES AND VOLCANIC ROCKS

(significant terms printed in **boldface**)

Volcanic rocks are solidified **magma**, molten material produced at depths of 75–150 km beneath the earth's surface. The chemical composition and physical properties of magma are variable, depending on the depth and temperature at which the rocks melt, the type of rocks that are melted, and the degree of solidification that occurs as the magma cools on the way to the surface. This variation produces a wide range of volcanic rocks and an equally varied array of landscape features resulting from volcanic eruptions. **Silica**, a compound of the elements silicon and oxygen, is the most important constituent of magma, comprising about 45–75 percent of the melt by weight.

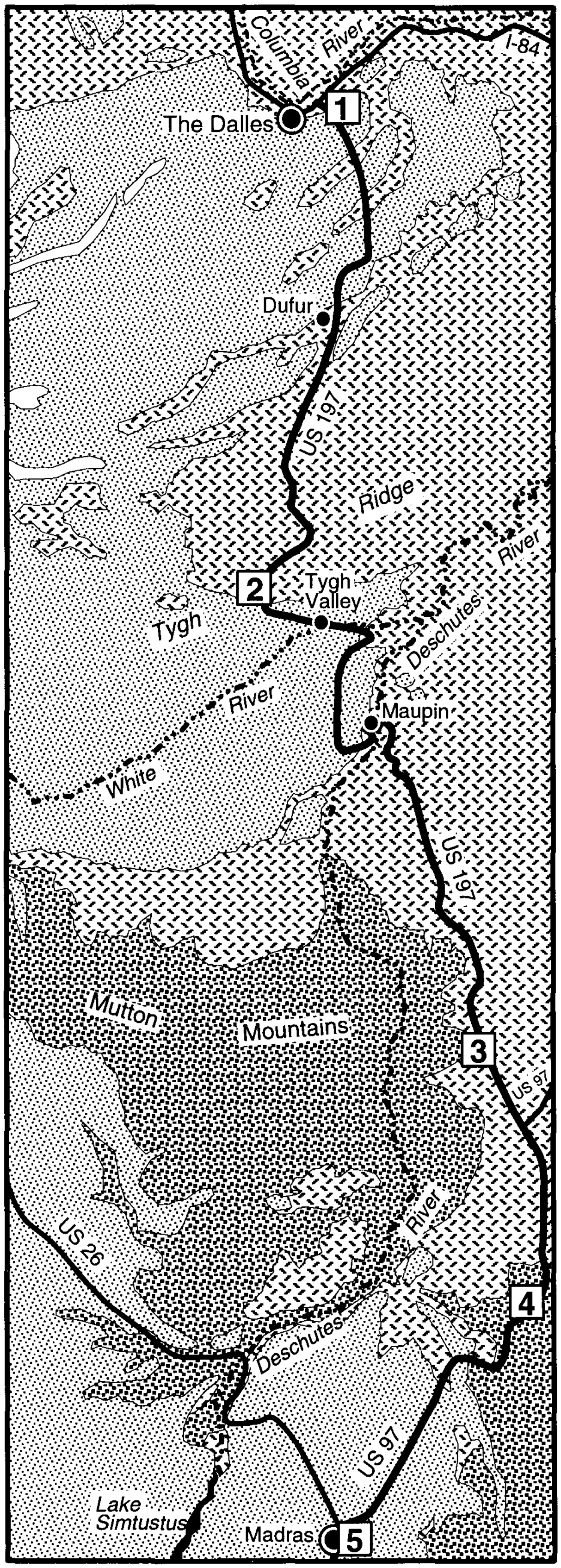
Volcanic rocks represent solidified **lava**, as magma is known when it reaches the earth's surface, and are named on the basis of silica content and the **silicate minerals** that they contain. Rocks formed by crystallization of relatively low-silica lavas are called **basalt**, those derived from high-silica lava are known as **rhyolite**, and the most common intermediate composition is named **andesite**. Low-silica lavas contain more iron and magnesium than higher silica varieties, which gives them darker colors. Basalt is generally dark gray or black, andesite is light gray or greenish gray, rhyolite is most commonly white, pink, or tan.

The composition of the magma not only determines what minerals will crystallize from it, but it also controls the nature of the volcanic eruptions that occur when the magma arrives at the surface. Basaltic lava is less **viscous** ("sticky") than andesitic or rhyolitic lava. Basaltic lava, therefore, is more fluid and moves as a thinner and more rapidly flowing lava flow. Andesitic and rhyolitic lavas show greater resistance to flow and generally do not travel more than a few miles from their eruptive **vents**. In some cases, silicic lava does not flow away at all, but accumulates as a high, steep-sided, bulbous mass of lava on top of the vent; these features are called lava **domes**.

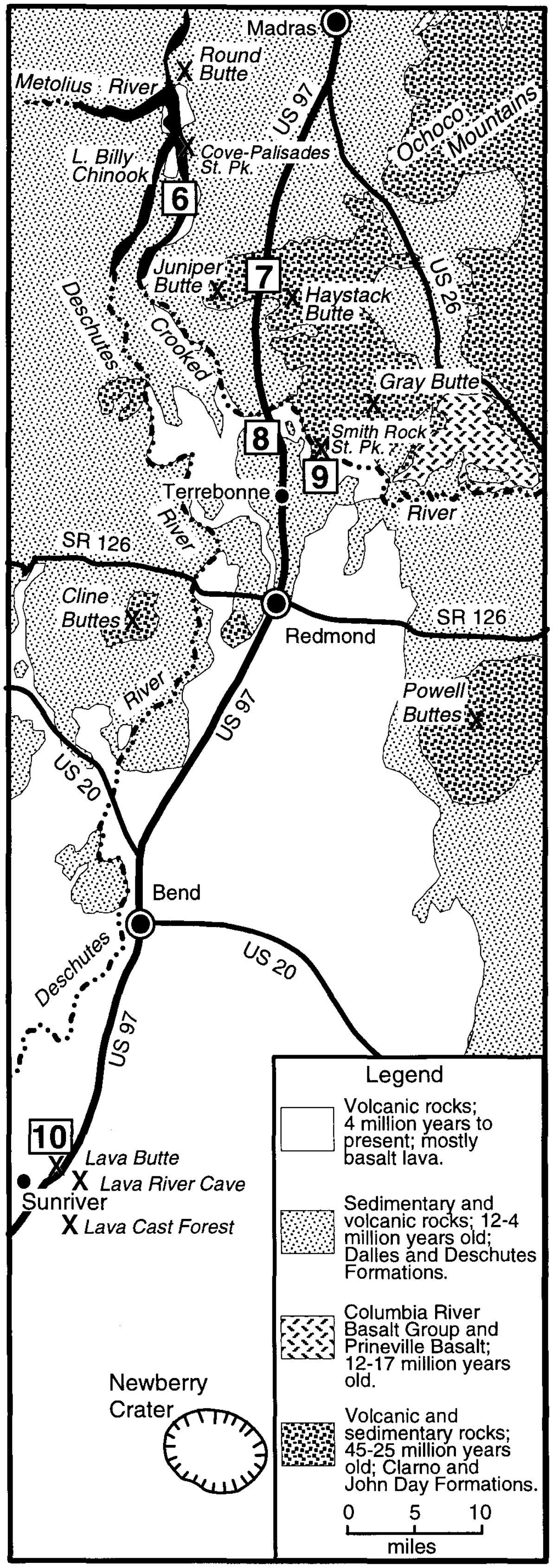
Volcanic eruptions are driven by gases that are dissolved in the magma where it is subjected to the great pressures of overlying rock within the earth. As the magma rises near to the earth's surface, this pressure diminishes until it is insufficient to keep the gas from forming bubbles in the melt. This process is analogous to the formation of bubbles in a carbonated beverage when the container is opened. Gas bubbles rise in the magma, pushing some of the magma along, and produce explosions when they burst through to the surface. Basaltic magmas contain less dissolved gas than more silica-rich magma varieties; consequently, eruptions of basaltic volcanoes are less violent than those occurring at andesitic or rhyolitic volcanoes.

During explosive eruptions, some of the bubble-rich lava is blown out as a froth, which is quickly quenched to volcanic glass upon contact with the cooler atmosphere and broken into fragments of widely ranging sizes as the bubbles continue to expand. These fragments, called **pyroclasts** (from Greek words meaning "fire broken"), include **volcanic ash**, **pumice**, and **cinder.** A rock formed of consolidated ash is called **tuff**.

Most pyroclastic fragments are blown skyward by volcanic explosions and fall back to the surface. The bulk of this fallout material accumulates adjacent to the vent from which it was erupted, but if the fragments are ejected to great height, a considerable volume may be carried away by the wind and fall back to the earth at great distances. The resulting deposits become thinner and composed of successively smaller particles at greater distances from the volcano. Because eruptions of gaseous rhyolite are the most violent, rhyolitic tuff is more voluminous and widespread than that of basaltic or andesitic composition. In some cases, rhyolitic and,



Columbia River
I-84
The Dalles
1
Dufur
US 197
Ridge
2
Tygh Valley
Tygh
Deschutes River
White River
Maupin
US 197
Mutton Mountains
3
US 97
River
US 26
4
Deschutes
US 97
Lake Simtustus
Madras
5



Madras
Round Butte
Metolius River
US 97
Ochoco Mountains
Cove-Palisades St. Pk.
L. Billy Chinook
6
Juniper Butte
7
Haystack Butte
US 26
Deschutes
Crooked
Gray Butte
8
Smith Rock St. Pk.
9
Terrebonne
River
River
SR 126
Cline Buttes
Redmond
SR 126
Powell Buttes
River
US 97
US 20
Bend
US 20
Deschutes
US 97
10
Lava Butte
Lava River Cave
Sunriver
Lava Cast Forest
Newberry Crater
Legend
Volcanic rocks; 4 million years to present; mostly basalt lava.
Sedimentary and volcanic rocks; 12-4 million years old; Dalles and Deschutes Formations.
Columbia River Basalt Group and Prineville Basalt; 12-17 million years old.
Volcanic and sedimentary rocks; 45-25 million years old; Clarno and John Day Formations.
0 5 10
miles

← **Generalized geologic map of road guide area: Left, The Dalles to Madras; right, Madras to Sunriver. Numbers refer to numbered sites in text.**

less often, andesitic pyroclasts are not simply ejected upward, but may flow downslope as rapidly moving, hot avalanches of ash and pumice, called **ash flows.** Ash flows may devastate hundreds of square miles adjacent to volcanoes. The resulting rocks, composed principally of pumice set in a matrix of finer ash and minerals crystallized from the magma are called **ash-flow tuffs.**

Volcanic landforms vary as a result of the difference in eruption character exhibited by magmas of different composition. Basaltic magma erupts without producing much pyroclastic material and generates fluid lava flows. Basaltic vents, therefore, are usually marked by small accumulations of cinder, called **cinder cones,** surrounded by extensive black, solidified lava. If large volumes of lava are erupted, they may construct a gently sloped **shield volcano.**

Andesitic magma generates more pyroclastic debris than basalt, and resulting lava flows are thicker and less extensive than those related to less siliceous magma. The resulting landforms are **stratovolcanoes** that are composed of alternating layers of lava and tuff (e.g., the major Cascade peaks). Because andesitic lavas are more viscous than basaltic ones, the slopes of stratovolcanoes are steeper than those of shield volcanoes.

Rhyolitic magma may also produce stratovolcanoes. More commonly, however, rhyolite is erupted in the form of pyroclastic material that falls or flows over a large area to produce extensive light-colored tuff. When rhyolite lava is erupted, it generally forms domes.

PERIODS OF VOLCANIC ACTIVITY IN CENTRAL OREGON

Eocene and Oligocene (45–25 million years ago)

The earliest volcanism recorded in central Oregon occurred during the geologic epochs of the Eocene and Oligocene. Volcanic rocks of this age are most common in the Ochoco Mountains, located to the east of U.S. Highway 97. The oldest of these rocks, referred to as the Clarno Formation, are present in the Mutton Mountains, northwest of Madras and are featured at the Clarno Unit of the John Day Fossil Beds National Monument east of Madras. Clarno Formation rocks are andesite lava flows and mudflow deposits—chaotic mixtures of andesite boulders and smaller fragments formed by landslides and rapid erosion of loose debris from the steep flanks of stratovolcanoes. Overlying the Clarno Formation is the John Day Formation, composed mostly of light-colored tuff recording the fallout of airborne ash from countless eruptions of ancient Cascade volcanoes. Eruptions from small rhyolite volcanoes in central Oregon also produced widespread ash-flow tuffs. Rhyolite lavas formed steep domes south of Madras. John Day Formation tuff and Clarno Formation mudflow deposits and associated sediment, are famous for the abundant and well-preserved plant and vertebrate fossils they contain. The story that these fossils tell about the climate and landscape of long-ago Oregon can be learned from visits to any of the various units of John Day Fossil Beds National Monument located in eastern Oregon.

Middle Miocene (17–12 million years ago)

The John Day Formation deposition was followed by several million years of erosion without any preservation of volcanic materials in central Oregon. This period ended at about 17 million years ago with the onset of eruption of the gargantuan lava flows referred to as the Columbia River Basalt Group. These basalt lava flows cover 63,000 mi^2 of Washington, Oregon, and Idaho to an average thickness of two thirds of a mile. If spread evenly over the state of Oregon, they would produce a layer 3,500 ft thick! Most of the basalt was erupted from long cracks, or **fissures,** located in northeastern Oregon and southeastern Washington; others were erupted in central Oregon near Monument. Similar Prineville Basalt is prominent near and south of Madras (Hooper and others, 1993).

The basalt lava was obviously very fluid to produce such extensive flows. It was also erupted so nonexplosively that very little material accumulated around the fissures to produce recognizable volcanoes. Instead, the sites of eruptions are now marked by the basalt fillings of the fissures themselves, called **dikes,** that can be seen in deep canyons subsequently cut through the basalt flows in central and northeastern Oregon. Over much of the northern half of our route we will see many of these lava flows as layers of dark basalt. The eruption of so much basalt dammed some streams to form lakes, repositioned some rivers to new courses, and reduced some to sluggish streams that meandered across the almost flat upper surfaces of the lava flows after they cooled. Sediment deposited by these streams can be seen as light-colored layers of sand and gravel between basalt flows. The sediment is composed primarily of ash, pumice, and rock fragments eroded from ancient Cascade volcanoes. These beds can be seen at several points along the route but have been officially named only in the area west and north of Madras, where they are called the Simtustus Formation (Smith, 1986).

Late Miocene and early Pliocene (12–4 million years ago)

During and following the eruption of the Columbia River Basalt Group flows, the crust of north-central Oregon and adjacent Washington was being horizontally compressed to produce wrinkled ridges and troughs that extend, more or less east to west, for distances of 40–125 mi. The uplifted areas are called **anticlines**, and the depressed areas are called **synclines**. Streams draining eastward from the Cascades followed the low ground of the synclines and deposited hundreds of feet of Cascade-derived sediment.

This sand and gravel is interleaved with far-traveled Cascade basalt lava flows and more silicic ash-flow tuffs, and numerous silicic ash- and pumice-fall layers that accumulated downwind from exploding volcanoes. These mixtures of sedimentary and volcanic materials vary in age and composition from one valley to the next and are largely referred to as the "Dalles Formation," in The Dalles basin and the Tygh Valley areas, and the "Deschutes Formation" in the Deschutes basin. Virtually none of the volcanoes of this vintage can still be seen in the Cascades; they have been eroded away or buried under younger volcanic products. The Dalles and Deschutes Formations, however, provide a decipherable record of Cascade volcanism at that time many millions of years ago.

Late Pliocene to Present (4–0 million years ago)

The modern High Cascade Range was largely built in the past two million years. Indeed, the major stratovolcano peaks were all formed in the last few hundred thousand years. Some relatively young volcanic activity also occurred in central Oregon, especially near the southern terminus of our route. Southeast of Bend is a large shield volcano, named "Newberry volcano," which grew in this position just east of the Cascades over the last 1.5 million years.

Some extensive lava flows from near Newberry volcano poured northward into the Deschutes basin to fill the Deschutes and Crooked River canyons as they were being incised into the older Deschutes Formation. Basaltic cinder cones litter the slopes on all sides of Newberry volcano, with the youngest ones extending northwestward along fractures, or **faults**, toward Bend.

Locally, especially south of Bend, layers of light-colored sandy ash along the road can be seen that represent fallout from the great eruption of Mount Mazama. This eruption occurred about 6,700 years ago and led to the formation of Crater Lake, 100 mi farther south in the southern Oregon Cascades.

Pillow basalt capped by columnar-jointed basalt at Site 1.

DESCRIPTION OF THE TRIP AND OF NUMBERED GEOLOGIC SITES

The entire extent of the trip could easily require more than one day. Keep this in mind as you make your trip plans. And although the main route is on well-maintained highways, be aware of weather conditions and possible closures on side roads.

This description of the tour leads south from The Dalles. In order to help users who might wish to travel from south to north, only interval distances are indicated.

SITE 1. BEGINNING OF TRIP, COLUMBIA RIVER BASALT GROUP OUTCROP, PILLOW BASALT

The Dalles, Oregon. Stop near top of hill on U.S. Highway 197, just south of bridge across Columbia River and interchange with Interstate 84. Parking available on west side of road.

The route along U.S. Highway 197 southward to the junction with U.S. Highway 97 features two rock formations: the basalt lava flows of the Columbia River Basalt Group and sediments of the Dalles Formation. The prominent roadcut at this locality illustrates the result of a Columbia River basalt flow entering a lake. When lava flows enter standing water, much of the lava is quenched to glass and broken into small fragments during the explosive generation of steam. Larger masses of lava detach from the main body of the flow but remain as coherent spherical or ellipsoidal blocks of quickly chilled, glassy basalt, which are referred to as **pillows**. Ellipsoidal pillows in the lower part of this roadcut are surrounded by ash that was generated by the interaction of the hot lava with the cold water, and is now altered to the yellow-orange mineral palagonite. The long axes of the pillows are oriented at an angle pointed downward toward the southwest, the direction in which the lava flow was moving. The unpillowed basalt at the top of the roadcut is part of the same lava flow that did not interact with the lake water, because it flowed where the pillows and ash had filled in the lake. The thickness of the pillow basalt, therefore, is a measure of the depth of the lake.

To the north are the Columbia Hills, an anticline uplift of folded basalt. Late Miocene sediments of the Dalles Formation accumulated in the basin south of this uplift and now form the bluffs along the south side of the city of The Dalles.

Between here and Dufur, 12.5 mi to the south, roadcuts expose basalt, including more pillow basalt, and consolidated sand, gravel, and tuff of the Dalles Formation. This material was derived about 7–12 million years ago from volcanoes that were in the vicinity of the present Mount Hood stratovolcano, which is intermittently visible from the road.

12.5 mi from The Dalles to Dufur.

10 mi from Dufur to summit on Tygh Ridge.

SITE 2. TYGH RIDGE SUMMIT

Use for orientation and preparation for 7-mi descent through Butler Canyon to Tygh Valley. About 4.5 mi down from the summit, note basalt quarry on east side of road. For side trip west ("county road" mentioned below), turn off about 2.5 mi farther, into Tygh Valley, and continue on Wamic Market Road toward Wamic. Oregon Trail historic marker and viewpoint about 2 mi up this road.

From Dufur southward to this point, U.S. Highway 197 climbs the flank of the Tygh Ridge anticline, which is underlain by folded basalt and defines the southern edge of The Dalles basin. The highway then descends the steeper south slope of the anticline through Butler Canyon. At least 20 flows of Columbia River basalt, totaling 1,000 ft in thickness, are exposed along the road. The basalt is black, as can be seen on freshly broken surfaces, but appears mostly rust colored because of surficial oxidation of iron and magnesium silicate minerals. These mineral crystals are not visible to the unaided eye, but reflections from small grains of another silicate mineral, **feldspar**, can occasionally be noted. Most of the basalts exhibit **columnar joints** generated by contraction of the cooling lava flow.

Close observation reveals numerous light-gray or tan layers of sediment and tuff between some basalt flows. These layers record deposition of river sediment and ash between basalt eruptions.

At the base of Butler Canyon the road enters the Tygh Valley basin. Dalles Formation sediment underlies most of the prominent mesa in the middle of the valley and can be seen in roadcuts along the county road that extends westward from the village of Tygh Valley toward Wamic. Younger sediment, tuff, and basalt, similar to the Deschutes Formation farther south, overlie the Dalles Formation, including the Juniper Flat basalt that the highway is built on for most of the route between Tygh Valley and Maupin. This basalt differs from the Columbia River basalts on Tygh Ridge by being lighter colored and containing easily visible crystals of white to glassy feldspar and green **olivine**. This lava flowed into a developing Deschutes River canyon to form a prominent bench upon which much of the town of Maupin is constructed.

10 mi from Tygh Valley to Maupin, where highway crosses Deschutes River.

View to the north across Tygh Valley and Butler Canyon on the flank of Tygh Ridge, the scene of Site 2.

17 mi from Maupin to Criterion Summit.

SITE 3. CRITERION SUMMIT AND MOUNTAIN IDENTIFIER

Pullout on west side of U.S. Highway 197.

A (sadly vandalized) monument at this site serves to identify the major Cascade volcanic peaks from Mount Adams, on the north, to the Three Sisters, toward the south, that can be seen from this point in clear weather. The Mutton Mountains, a northeast-southwest oriented uplift underlain by volcanic rocks of the Clarno and John Day Formations lie prominently in the foreground, trending toward Mount Jefferson. These same formations form the Ochoco Mountains, which are visible on the skyline to the south and southeast. John Day Formation rhyolite forms the prominent peaks of the western Ochoco Mountains on the horizon directly south of the viewpoint. Columbia River basalt flows lapped up onto the older volcanic rocks from the north, east, and south, and underlie this site, where they are quarried by the transportation department on the east side of the highway.

The major Cascade peaks are primarily andesite stratovolcanoes, although Three Fingered Jack and Mount Washington are transitional between basalt and andesite, and the lower parts of these cones are broad, gently sloping shields. There are also many small shield volcanoes and cinder cones in the Oregon Cascades, the youngest and most spectacular of which are along McKenzie Pass on Oregon Highway 242, about 50 mi to the west of Bend.

Of the volcanoes visible from here, only Mount Adams, Mount Hood, and South Sister have experienced eruptions since the last ice age glacier advances, 10,000 years ago. Moving glaciers scoured deeply into the easily eroded stratovolcanoes and modified originally smooth cones into sharp ridges, pinnacles, and spines that are best illustrated by Three Fingered Jack, Mount Washington, and the summit area of Mount Jefferson. The most recently active volcano seen from this viewpoint is Mount Hood, which last erupted in about A.D. 1800. Pyroclastic debris from that eruption was washed down river valleys in great floods that reached the Columbia River near Troutdale and through the White River valley to the Deschutes River near Tygh Valley, north of this point.

Mutton Mountains and Mount Jefferson, as seen from Criterion Summit, looking west.

5 mi from Criterion Summit to intersection of Highways 197 and 97. Continue on Highway 97.

2 mi from intersection to rest area on west side of highway; beginning of descent through Cow Canyon.

2.7 mi from rest stop to basalt quarry on east side of road.

3.5 mi from quarry to intersection of Highways 97 and 293; entering valley.

0.4 mi from intersection to historical marker (Cross Keys Post Office on Trout Creek, 1879).

SITE 4. HAY CREEK—TROUT CREEK VALLEY

Rocks in this area are among the oldest to be seen along this route. Highway 97 descends through a thick sequence of Columbia River basalt in Cow Canyon. The valleys of Hay and Trout Creeks are eroded in sediment and ash-flow tuff of the John Day Formation that underlie the basalt. One ash-flow tuff, with a distinctive brick-red color, is quarried for building stone just east of the highway.

From here southward to Bend, Highway 97 traverses the Deschutes basin, bounded by the Mutton Mountains to the north, the Ochoco Mountains to the east, the High Cascades to the west and the High Lava Plains near Newberry volcano to the south.

2.8 mi from historical marker to turnoff "To Hay Creek Road" to the east. A short side trip on that road allows a better look at red tuff quarry.

15 mi from Hay Creek Road turnoff to intersection of Highways 97 and 26 at Madras.

SITE 5. MADRAS

No particular stopping point. Continue through Madras on Highway 97.

The city of Madras rests in a bowl-shaped valley eroded in sediment of the Deschutes Formation, which is noted as light brown sandstone in numerous roadcuts and building excavations within and near the town. There are also lava flows in the Deschutes Formation,

Cove Palisades State Park. View is to the west from a rim viewpoint, showing the park road passing between The Ship (left) and The Island (right).

including the prominent rimrock basalt flow capping the mesa along the west side of town. This lava flow was erupted about 5.3 million years ago from a group of cinder cones, named Tetherow Buttes, located near Terrebonne, about 20 mi to the south of here.

2.5 mi from Highways 97/26 intersection to turnoff east for Highway 26. Continue on Highway 97.

6.8 mi to first turnoff for Cove Palisades State Park at Iris Lane. (Various other possibilities exist to reach the park.)

5.2 mi to park entrance.

SITE 6. COVE PALISADES STATE PARK

This park features spectacular canyon scenery and geologic features near the confluence of the Deschutes, Crooked, and Metolius Rivers. For a more detailed discussion of this park, see earlier articles in Oregon Geology (Bishop, 1990; Bishop and Smith , 1990; Smith, 1991).

About 7-mi round trip from entrance to four viewpoints (going north along canyon rim; road continues to Round Butte Dam viewpoint.

About 10-mi round trip from entrance to petroglyphs (descending into canyon).

Highlights of COVE PALISADES STATE PARK

This state park, reached by well-marked roads to the west of U.S. Highway 97, is a most impressive scenic locality where the Deschutes, Crooked, and Metolius Rivers meet in a plexus of 1,000-ft-deep canyons now flooded by the waters of Lake Billy Chinook behind Round Butte Dam. A short excursion to The Cove affords an opportunity to see some of the geologic record of ancient Cascade volcanoes.

Viewpoints above the east side of the park

Four viewpoints over the park, reached by a paved road above the eastern edge of the canyons, provide a dramatic panorama of central Oregon geology. The major Cascade peaks of Mount Hood, Mount Jefferson, Three Fingered Jack, Mount Washington, The Three Sisters, Broken Top, and Mount Bachelor form the backdrop to the west on sufficiently clear days. Basalt lava flows 4–5 million years old, from the Cascades and small, nearby volcanoes, form the prominent rimrocks and flat surfaces extending away from the canyons.

One of the local volcanoes, Round Butte, is a gently sloping shield volcano surmounted by a small cinder

Newberry basalt cliffs at the Cove Palisades State Park, seen from the canyon rim on the east side of the park.

cone directly north of the viewpoints. An older rhyolite lava dome within the John Day Formation forms Juniper Butte, looming to the south.

The varicolored rocks exposed in the canyon walls are sand, gravel, lava, and ash-flow tuff of the Deschutes Formation that, at this locality, were largely discharged eastward from the Cascades over a period of only a few hundred thousand years during the late Miocene. A prominent, narrow projection of black basalt, rising 550 ft above the lake, separates the Deschutes and Crooked Rivers to form The Island in the middle of the park. This lava flow, determined by radioactive-isotope-decay methods to be about 1.2 million years old, was erupted near Newberry volcano, visible on clear days 60 mi away on the southern horizon. It poured into the Crooked River canyon, already cut to its present dimensions, and continued downstream past the confluence with the Deschutes River for another 3 mi. The rivers carved their canyons anew, leaving The Island and a number of conspicuous wedge-shaped accumulations of basalt clinging to the canyon walls as the record of this great eruption. The prominent columns and other fanning and random arrangements of fractures within the basalt of The Island were produced by contraction during solidification and cooling of the basaltic lava.

The Ship

This prominent locality near the center of the park, provides a perspective on the geology from within the great canyons. Adjacent to the parking area is displayed a basalt boulder with petroglyphs that was retrieved from the Crooked River Canyon before the reservoir was filled.

From this vantage point one can look directly northward at the south end of the basalt flows of The Island. Before the eruptions of these lavas, the Crooked and Deschutes Rivers met at this point; now the confluence is another 2 mi downstream to the north.

Looking southward at the prow of The Ship, one can see some of the material that makes up the Deschutes Formation. Sand and gravel represent ancient streams that flowed eastward from the Cascades. The prominent white layer and the irregularly eroded pinkish-gray unit near the bottom of the exposure are ash-flow tuff. Inspection of the lower tuff along the parking area shows the typical texture of ash-flow tuffs, with chunks of pumice and volcanic fragments in a fine, abrasive matrix of ash.

Do not climb the fragile slopes of The Ship itself!

Similar layers of sediment, ash-flow tuff, and lava can be examined along the roadcuts above the Crooked

Deschutes Formation at The Ship in Cove Palisades State Park. View is from canyon rim on east side. Black Butte is visible on the center skyline.

River and Deschutes River arms of Lake Billy Chinook.

Also prominent along these canyon walls are chaotic masses of Deschutes Formation and the younger basalt that are tilted, so that the layers are no longer horizontal: these are landslides. These landslides have caused substantial damage to the State Park roadway just east of The Ship, but have also been beneficial by producing relatively flat areas within the otherwise steep-walled canyon that are utilized for campgrounds and day-use areas west of The Ship and the facilities at the marina.

About 8 mi from park entrance to return to Highway 97 and to top of saddle between Juniper Butte and Haystack Butte.

SITE 7. JUNIPER BUTTE GRADE

No particular stopping point.

At this point, Highway 97 crosses a saddle between Juniper Butte on the west and Haystack Butte on the east. The Buttes mark the western edge of the Ochoco Mountains, a part of the Blue Mountains, which extend 200 mi northeastward into southeastern Washington. Most high peaks and ridges in this area are composed of volcanic rocks of the John Day Formation. Juniper Butte is a rhyolite dome, as is Cline Buttes, visible about 15 mi to the south. Tilted layers of ash-flow tuff comprise Haystack Butte and are also exposed along the highway in roadcuts. South of Haystack Butte and about 5 mi distant is Gray Butte, composed of basalt flows and sediment containing leaf fossils, and topped by a thick, rhyolitic lava-flow cap. The leaf fossils document a change from subtropical to temperate climate in central Oregon between 30 and 40 million years ago (Ashwill, 1983). On the southern horizon, about 50 mi distant, is the Newberry volcano, a broad basaltic shield.

6.4 mi from top of saddle to Ogden Wayside

SITE 8. PETER SKENE OGDEN STATE SCENIC VISTA

(New official name for what used to be a state park)

This wayside provides an overlook of the 330-ft-deep Crooked River gorge. The railroad bridge to the west of the highway was completed in 1911 and was the final hurdle in a nearly decade-long effort to construct a railroad into central Oregon.

Looking under the highway bridge, one can see a vertical cliff of basalt erupted from Tetherow Buttes, about 4 mi to the south—the same lava flow as seen at Madras to the north. Following the eruption of this basalt, about 5.3 million years ago, the Crooked River

Juniper Butte, the western edge of the Ochoco Mountains. View is to the northwest. Lava flows erupted from Tetherow Butte underlie fields in the foreground.

cut this canyon to its present depth prior to about 1.2 million years ago. At that time, a voluminous series of lava flows from Newberry volcano, about 40 mi to the south, flowed into the Crooked River gorge and, at this point, filled it to overflowing. The lava formed the dark cliffs of basalt that can be seen extending along both sides of the river from the highway bridge to the turn in the river downstream from the railroad bridge. The canyon was recut in the same position afterward. Spectacular cliffs composed of this same canyon-filling lava flow can be seen in The Island at Cove Palisades State Park.

3.2 mi from Peter Skene Ogden wayside to turnoff (east) to Smith Rock State Park.

SITE 9. SMITH ROCK STATE PARK

A 3.5-mi side trip from U.S. Highway 97 brings you to this famous rock climbers' challenge. The 600-ft-high rock massif with castellated vertical cliffs represents a small rhyolitic volcano in the John Day Formation. The rock is indurated tuff that was generated by very violent explosions resulting from the chance interaction of a rising rhyolite magma and shallow groundwater. The water quenched the magma to glass that was pulverized and ejected as very fine ash when the water was explosively converted to steam. The resulting **tuff cone** was centered below the visitors' overlook and includes all of the yellow-brown rocks that rise above the river along its wide curve from the east. In the ensuing 30 million years or so, the tuff cone was tilted to the southeast during uplift of the Ochoco Mountains and deeply dissected by streams.

6.3 mi from turnoff to intersection of Highways 97 and 126 in Redmond. Continue on Highway 97.

14.4 mi from Redmond to intersection of Highways 97 and 126 in Redmond. Continue on Highway 97.

9.7 mi from Highways 97/126 intersection to entrance to High Desert Museum, on east side of highway (information at 541–382–4754).

4.7 mi from High Desert Museum to entrance for Lava Lands Visitor Center (information from U.S. Forest Service, phone in Bend 541-593-2421).

SITE 10. LAVA LANDS VISITOR CENTER AND LAVA BUTTE

South of Bend, U.S. Highway 97 climbs out of the Deschutes basin and onto a high, pine-covered plateau

Crooked River Gorge at Peter Skene Ogden State Scenic Vista. View is to the west, approximately from the location of the highway crossing.

of volcanic rock. At the surface, these rocks are primarily basalt lava flows and associated cinder cones flanking the large Newberry volcano shield. Many of these basalt flows are less than 10,000 years old and retain many of the fragile surficial features that are characteristic of freshly erupted lava and are generally lacking with the older basalts that have been examined along the route farther to the north. The youngest lavas have little or no vegetation on them, giving the area a stark moonscape appearance, which was utilized for the training of Apollo astronauts in 1966. The U.S. Forest Service Lava Lands Visitor Center is now part of what was established in 1990 as the Newberry National Volcanic Monument.

Lava Lands

A variety of interesting volcanic features can be seen in this unique geological area along or near U.S. Highway 97 south of Bend, including Lava Butte, Lava River Cave, and Lava Cast Forest. Trails and interpretive guides to these features are provided by the U.S. Forest Service, which operates the Lava Lands Visitor Center near Lava Butte. A stop at the visitor center is highly recommended, as is a visit to the nearby High Desert Museum. The Lava Lands area is low on the northwest flank of the great Newberry shield volcano, which is best seen from the top of Lava Butte. Dozens of young cinder cones dot the flank of Newberry volcano, with the youngest cones and associated basalt lava flows extending along a northwest fault zone to Lava Butte.

Lava Butte (Generally closed from October through March)

Lava Butte is a cinder cone, about 6,160 years old, that can be explored along foot trails and by a paved road to the summit. From the summit observation tower, one can see Newberry volcano to the southeast, the broad Deschutes basin to the north beyond Bend, and a panorama of the High Cascade Range to the west. A trail leads around the 150-ft-deep summit crater. Views to the southeast from this trail across U.S. Highway 97 show smaller accumulations of basaltic spatter that formed along the same fracture through which magma rose to feed Lava Butte. One can also see an accumulation of black spatter around the vent that fed the lava flows surrounding the base of Lava Butte. These lava flows cover about 6,100 acres and have a total volume of approximately 375 million cubic yards.

1.2 mi from visitor center to entrance to Lava River Cave.

Smith Rock at Smith Rock State Park. View is to the southwest from viewpoint in the park.

Lava River Cave (Closed November 1 to April 15 for protection of hibernating bats)

This dramatic volcanic feature is associated with a lava flow erupted before the formation of Lava Butte. The basalt flow cooled and solidified along its edges and top, while molten lava continued to flow within an interior tube. The molten lava eventually drained away downslope, and the solidified walls and roof were strong enough to keep the empty tube open over most of its length as a cave.

A hike into Lava River Cave provides an opportunity to view the interior of a 5,200-ft-long segment of this lava tube with access gained through a point where the roof of the tube collapsed. More than two dozen similar lava tube caves are known in other basalt flows surrounding Newberry volcano.

3.8 mi from entrance to Lava River Cave to turnoff to east on Forest Service Road 9720 to Lava Cast Forest (also turnoff west to Sunriver and Mount Bachelor).

Lava Cast Forest (Road may at times be closed because of snow)

This fascinating geologic area is reached by an about 20-mile round trip excursion from U.S. Highway 97 on Forest Service Road 9720, which intersects U.S. Highway 97 near milepost 153. A short hike along the interpretive trail provides insight into what happens when basalt lava flows into a forest.

About 6,000 years ago, a basalt lava flow, erupted from fissures located just north of the parking area, entered a forest. The fluid basaltic lava quickly chilled to glass where it came in contact with the colder trees. The trees were, of course, consumed by fire. Lava flowing unimpeded between the burning trees, however, continued downslope, and as the level of the lava flow fell, the locally solidified basalt surrounding former trees projected as hollow columns above the upper surface of the solidifying flow. Many of these low, collarlike columns remain. The interior void represents a mold of the tree trunk that was burned by the solidifying lava. Because of the fluid characteristics of basalt lava, the interiors of some molds include detailed casts of the bark and charred wood of the exterior of the tree.

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Bishop, E.M., 1990, Field trip guide to Cove Palisades

(Continued on page 17)

Lava Butte at the Lava Lands visitor center.

Newberry volcano as seen from the top of Lava Butte.

Tree mold in lava flow at Lava Cast Forest.

(Continued from page 15)

State Park and the Deschutes basin: Oregon Geology, v. 52, no. 1, p. 13–16.

Bishop, E.M., and Smith, G.A 1990, A field guide to the geology of Cove Palisades State Park and the central Deschutes basin in central Oregon: Oregon Geology, v. 52, no. 1, p. 3–12.

Hooper, P.R., Steele, W.K., Conrey, R.M., Smith, G.A., Anderson, J.L., Bailey, D.G., Beeson, M.H., Tolan, T.L., and Urbanczyk, K.M., 1991, The Prineville basalt, north-central Oregon: Oregon Geology, v. 55, no. 1, p. 3–12.

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SUGGESTED FURTHER READING

East of the Cascades, by Phil Brogan; Binford and Mort, 1977, 304 p.

High and Mighty: Selected Sketches about the Deschutes Country, edited by Thomas Vaughan; Oregon Historical Society, 1981, 309 p. □

DOGAMI PUBLICATIONS

Released November 10, 1997

Chronic geologic hazard maps of coastal Lincoln County, Oregon, by George R. Priest. Open-File Reports O-97-06 through O-97-10, $6 each.

These five maps revise previously published information on landslide hazards and erosion rates along the coast of Lincoln County. The stretch of coastline affected by the revision extends from slightly north of Otter Rock to the north jetty at Newport and about 1.5 mi inland from the shore. The maps serve as basic resources for land-use planning decisions, emergency management planning, and insurance purposes.

The revised maps have been released under the original title and replace the original Open-File Reports O-94-22 through O-94-26. They are based on photo maps, each of them covering a small stretch of coastline. Chronic geologic hazards are mass movement hazards such as landslides, slumps, rock toppling, and soil or rock flows. These, along with shoreline geology and shoreline erosion rates, are shown on the maps.

The table below lists the revised maps and the original maps that are replaced by them:

Map area	New map number	Replaces
Otter Crest area	O-97-06	O-94-22
Beverly Beach area	O-97-07	O-94-23
Moolack Beach area	O-97-08	O-94-24
Moolack-Agate Beach area	O-97-09	O-94-25
Newport area	O-97-10	O-94-26

Explanations and an abbreviated erosion-rate table were originally released as DOGAMI Open-File Report O-94-11 and are not affected by the revision.

The revised maps have been deposited in those places where the original complete set of maps is available to the public. This includes the public libraries of Lincoln City and Newport, the Lincoln County Library District, and the libraries of the Hatfield Marine Science Center and Oregon Coast Community College in Newport. Other libraries that have complete sets are the State Library in Salem, the Multnomah County Library in Portland, and the academic libraries of the University of Oregon, Eugene; Oregon State University, Corvallis; Portland State University, Portland; Southern Oregon University, Ashland; and Eastern Oregon University, La Grande. Complete or partial sets including the maps appropriate for the region are in the planning offices of Lincoln County, Lincoln City, Depoe Bay, and Newport.

All maps must be ordered in Portland and will be printed on demand. Allow two weeks for delivery.

Erosion and flood hazard map, coastal Lincoln County, Oregon, by George R. Priest. Open-File Reports O-97-12 through O-97-30, $6 each.

Coastal shoreline change study, northern and central Lincoln County, Oregon, by George R. Priest. Open-File Report O-97-11, 45 p., $6.

The series of 19 maps delineates erosion and flood hazard areas, each of them covering a small stretch of coastline, along 31 mi of the Lincoln County coast, from Salmon River to Seal Rocks. The study was conducted to provide the Federal Emergency Management Agency (FEMA) with data for estimating insurance costs to the federal government should it provide coastal erosion coverage to coastal residents. The methods, results, and applications of the study are explained and discussed in the separate text report.

The maps are based on vertical aerial photos at the scale of 1:4,800 (1 in. on the map=400 ft on the ground). Along the total extent of map coverage, they show the current and 60-year positions of an "erosional reference feature," such as the top of a bluff or the headwall of a landslide. Erosion-rate data published earlier (DOGAMI Open-file Report O-94-11) and shown in the margin of the new maps were used to indicate the respective position of the "erosional reference feature" 60 years from now. Active landslide areas are especially emphasized. In a similar way, lines were drawn to indicate the current and 60-year positions of 100-year flood zone boundaries. For the identification of flood zones, standard FEMA terminology was used.

Complete sets of the maps have been made available in the public libraries of Lincoln City and Newport, the Lincoln County Library District, and the libraries of the Hatfield Marine Science Center and Oregon Coast Community College in Newport. Other libraries that have complete sets are the Oregon State Library, Salem; the Multnomah County Library, Portland; and the academic libraries of the University of Oregon, Eugene; Oregon State University, Corvallis; Portland State University, Portland; Southern Oregon University, Ashland; and Eastern Oregon University, La Grande. Complete or partial sets including the maps appropriate for the region are in the planning offices of Lincoln County, Lincoln City, Depoe Bay, and Newport.

The open-file report numbers of individual maps are as follows:

Salmon River area	O-97-12
Roads End area	O-97-13
Lincoln City-Wecoma Beach area	O-97-14
Lincoln City-D River area	O-97-15
Taft-Siletz Spit area	O-97-16
Gleneden Beach-Siletz Spit area	O-97-17
Fogarty Creek-Lincoln Beach area	O-97-18
Boiler Bay area	O-97-19
Depoe Bay area	O-97-20
Cape Foulweather-Whale Cove area	O-97-21
Otter Crest area	O-97-22
Beverly Beach area	O-97-23
Moolack Beach area	O-97-24
Moolack-Agate Beach area	O-97-25
Newport area	O-97-26
South Beach area	O-97-27
Newport Airport area	O-97-28

Lost Creek area	O–97–29
Seal Rock area	O–97–30

All reports can be purchased. Report O–97–11, containing the explanations, costs $6 and should always be purchased together with the maps. Maps cost $6 each. The complete set of maps and explanatory text costs $100. The maps must be ordered in Portland and will be printed on demand. Allow two weeks for delivery.

Released December 3, 1997

Relative Earthquake Hazard Map of the Portland Metro Region, Clackamas, Multnomah, and Washington Counties, Oregon, by Matthew A. Mabey, Department of Geology, Brigham Young University; Gerald Black and Ian Madin, DOGAMI; Dan Meier, Woodward-Clyde Consultants of Portland; T. Leslie Youd, and Celinda Jones, Department of Civil and Environmental Engineering, Brigham Young University; and Benjamin Rice, Metro Regional Services. DOGAMI map IMS–1, full-color, scale 1:62,500 (about 1 in. to the mile), $12.

DOGAMI and Metro Regional Services have jointly released the first combined map of relative earthquake hazards that covers the entire area within the Portland metropolitan boundaries, from Forest Grove to Troutdale and from Hayden Island to Wilsonville. It indicates which areas will be most severely affected by earthquakes. The map, which encompasses 24 cities and 1.3 million people, is the culmination of a four-year effort involving the Federal Emergency Management Agency, Metro and DOGAMI. Consulting firms contributing to the map include Dames and Moore, Shannon and Wilson, Fujitani-Hilts, Squier Associates, Kelly Strazer, and Geotechnical Resources, Inc.

The 3- by 5-ft map also includes smaller maps showing the three types of ground responses during an earthquake—liquefaction, ground motion amplification, and slope instability. These hazards were used to determine the overall relative earthquake hazards shown on the large map.

Research on earthquake damage in other parts of the world has demonstrated that earthquake damage varies from area to area because of differences in the way the ground responds to earthquakes. Studies were made of the ground and rock at locations covered by this map to determine how they would respond to an earthquake. That information was used to develop the hazard maps.

Along with the map, Metro also released a new software program to help planners and emergency managers use earthquake hazard information collected over the past few years: *Metro Area Disaster Geographic Information System (MAD GIS) CD-ROM.* This software will be given to local and state emergency managers and will later be made available to other agencies and the public at the cost of production and distribution.

In recent years, DOGAMI has released more detailed relative earthquake hazard maps of the Portland, Mount Tabor, Lake Oswego, Beaverton, Gladstone, and Linnton quadrangles, as well as areas in Vancouver, Wash.

The new map is available rolled or folded for $12 (add $5 for mailing rolled maps). Earlier published earthquake hazard maps are also available from the same outlets.

For information on MAD GIS CD-ROM, contact Mike McGuire of Metro at (503) 797-1823.

Released December 15, 1997

Cascadia Subduction Zone Tsunamis: Hazard Mapping at Yaquina Bay, Oregon. Final technical report to the National Earthquake Hazard Reduction Program, by George R. Priest, DOGAMI; Edward Myers and António M. Baptista, Oregon Graduate Institute of Science and Technology; Paul Fleuck and Kelin Wang, Geological Survey of Canada; Robert A. Kamphaus, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration; and Curt D. Peterson, Portland State University. Open-File Report O–97–34, 26-pages, 118 pages appendices, $10.

This new report describes the development of tsunami hazard mapping techniques for application to the Yaquina Bay area in coastal Lincoln County. The study was conducted for the National Earthquake Hazard Reduction Program (NEHRP) and is principally aimed at providing information for emergency management planning. The report will be used by DOGAMI in the production and publication of tsunami hazard maps for this and other coastal areas.

Potential tsunami flooding from Cascadia subduction zone earthquakes at Yaquina Bay in Newport, Oregon, was explored by simulating fault ruptures and resulting tsunamis. Flooding from most scenario tsunamis is modest, because of protection by large jetties and sand dunes that guard Yaquina Bay. However, a worst-case tsunami reaches elevations of 35 ft at the open coast and floods all lowlands 1.5 mi inland. Flooding from scenario tsunamis reaching elevations of 12 and 27 ft at the open coast was also mapped to illustrate the range of uncertainty in the mapping technique.

Three scenario earthquakes were chosen in order to provide useful planning scenarios for tsunami hazard mitigation at Yaquina Bay. Inundation for high, moderately high, and moderately low runup cases were mapped, corresponding, respectively, to (1) a magnitude 9+ earthquake with an asperity immediately offshore (an asperity is a rough spot at the interface of the slipping plates that causes more fault movement), (2) the same earthquake without an asperity, and (3) a magnitude 8.5 earthquake with about half the fault slip of the magnitude 9+ case. Resulting open coastal runup elevations at Newport were 36, 26, and 16 ft, respectively. □

Tree ring studies establish A.D. 1700 as year of huge Cascadia earthquake

by Shannon Priem, Oregon Department of Geology and Mineral Industries

Growth rings of ancient trees confirm that an earthquake in North America sent ocean waves to Asia almost three centuries ago, according to two groups of American scientists.

The scientists, in reports that have recently appeared in the journals *Nature* (Yamaguchi and others, 1997) and *Geology* (Jacoby and others, 1997), present tree-ring dates for an earthquake and tsunami that had been previously inferred from geologic observations in the northwestern United States and adjacent Canada. Scientists have compared these dates with the time of a tsunami known from village records in Japan. The agreement is so remarkable, the scientists say, that the Japanese records become written proof that the earthquake really happened.

At issue is the threat posed by an active fault that dwarfs the San Andreas fault and underlies a mostly offshore area from southern British Columbia to northern California. This fault—the Cascadia Subduction Zone—caused little concern until the late 1980s, when scientists began to recognize geologic evidence that the fault has produced earthquakes of magnitude 8 or larger. The most recent of these events was soon dated by radiocarbon methods to the decades between A.D. 1680 and 1720.

These dates caught the attention of Japanese researchers, who checked Japanese village records for signs of an "orphan" tsunami between 1680 and 1720. They found just one candidate, and they used its size and date to calculate that the Pacific Northwest had had an earthquake close to magnitude 9 in January of 1700. Their report was published early last year, in *Nature* (Satake and others, 1996).

American scientists responded by setting out to learn whether their Japanese colleagues had identified the correct year and season of a huge Pacific Northwest earthquake. One team, led by David Yamaguchi of the University of Washington in Seattle, studied trees killed by an earthquake near the mouth of the Columbia River. Another team, led by Gordon Jacoby of Lamont-Doherty Earth Observatory in Palisades, New York, focused on trees that barely survived it.

Each tree-ring team concludes that a huge Pacific Northwest earthquake occurred in the months between August 1699 and May 1700—dates that indeed converge on the time of the January 1700 tsunami in Japan.

The scientists report that trees killed by the earthquake died sometime after the 1699 growing season ended, but before the 1700 growing season began. In addition, the Jacoby team describes signs of trauma that begin with the 1700 ring of several of the trees that survived the earthquake.

The Yamaguchi team also addresses the controversy about the maximum size of Pacific Northwest earthquakes. Previously, some earth scientists had inferred nothing larger than magnitude 8, while others proposed magnitude 9, which is many times larger in terms of energy released, geographic area, and duration of shaking.

Writing in *Nature*, the researchers contend that a huge earthquake is now more plausible, because the new tree-ring dates fail to show that the 1700 event was smaller than magnitude 9.

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Satake, K., Shimazaki, K., Tsuji, Y., and Ueda, K., 1996, Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January 1700: Nature, v. 379, p. 246–249. □

DOGAMI honors volunteers

The Oregon Department of Geology and Mineral Industries (DOGAMI) honored all those who volunteered their help to the Department at its annual award dinner held last December.

With their efforts, volunteers have greatly enhanced the department's effectiveness, especially in operating the Nature of the Northwest Information Center, maintaining and developing the department library, and assisting in the department's publication program.

Volunteers have been working with DOGAMI since 1991 and have donated over 9,000 hours in the program. All volunteers have their hours recorded and tallied and receive annual certificates showing their total cumulative hours. Each person who works more than 500 hours receives a gift: an engraved clock for over 500 hours, an engraved pen for over 1,000 hours, and a $50 gift certificate to the Lloyd Center shopping mall for over 1,500 hours.

At the 1997 award dinner, State Geologist Donald Hull presented certificates and gifts to the following volunteers:

John Westgate, 59 hours
Dorothy Blattner, 278 hours
Phil Johnson, 471 hours
Phyllis Thorne, 538 hours

Charlene Holzwarth, 690 hours
Rosemary Kenney, 1,348 hours
Archie Strong, 1,501 hours

The following volunteers were unable to attend the dinner:

Brenda Dolby (Albany), 71 hours
Sonja Bruce, 92 hours
Esther Kennedy, 202 hours
Joan Konner, 512 hours (clock)
Jan Murphy, 749 hours (clock in 1996). □

Smithsonian has new hall of geology, gems, and minerals

The Smithsonian National Museum of Natural History in Washington, D.C. opened what has been termed "the most ambitious exhibition renovation on the Mall in decades" on September 20, 1997: the Janet Annenberg Hooker Hall of Geology, Gems, and Minerals.

The 20,000-square-foot hall, closed since 1995 for the renovation, was modernized with the help of $13 million in private donations and a team of more than 100 designers, scientists, architects, engineers, artists, educators, writers, and researchers. It features many state-of-the-art presentations, including interactive computer components, animated graphics, special lighting effects, and hands-on specimens. The hall includes more than 3,000 objects, 14 computer stations, two study stations with additional computer interactives, and eight short video presentations. Visitors can see the highlights of the hall by following a "Fast Track" that displays the major pieces in each gallery just in front of the detailed cases with other materials.

Hooker Emerald, 75.47 carats, surrounded by 109 round and 20 baguette diamonds (totaling 13 carats) in platinum. Emerald from Colombia. Current brooch setting by Tiffany and Co. Gift of Mrs. Janet Annenberg Hooker, 1977. Displayed in the National Gem Collection. Photo courtesy National Museum of Natural History, Smithsonian Institution.

Iron pyrite cubes, a specimen from sedimentary deposits near Lagrono, Spain, displayed in the Minerals and Gems Gallery. Photo courtesy National Museum of Natural History, Smithsonian Institution.

Six of the seven galleries that make up the hall are open now; a seventh, the Rocks Gallery, is scheduled to open in 1998 and is to explain rock formation, including the impact of the forces of wind and water at the Earth's surface and those of intense heat and pressure deep within the Earth. The six open galleries are as follows:

1. Harry Winston Gallery, which houses several geologic wonders, such as the 45.52-carat Hope diamond, the Tucson meteorite, a 1,300-lb quartz crystal, and a 324-lb natural copper sheet;

2. National Gem Collection with the museum's unparalleled collection of gemstones and jewelry pieces;

3. Minerals and Gems Gallery with more than 2,000 remarkable crystal specimens emphasizing mineral science and the importance of minerals in everyday life;

4. Mine Gallery, showing crystal pockets and ore veins in dioramas of historic mines and offering displays of minerals, computer interactive displays, and video displays about mining, from ore to final product;

5. Plate Tectonics Gallery, illustrating how earthquakes, mountain chains, and volcanoes result from the constant shifting of plates on the earth's surface;

6. Moon, Meteorites, and Solar System Gallery, which explores the birth of our solar system and its evolution through film, computer interactives, and touchable specimens, including Moon rocks, the mars meteorite and other meteorites, and stardust.

Curator-in-charge Jeffrey E. Post and photographer Chip Clark have produced a book titled *The National Gem Collection* and published in conjunction with the opening of the new hall (National Museum of Natural History/Harry N. Abrams, Inc., 1997).

The National Museum of Natural History is located at Constitution Avenue and 10th Street NW, Washington, D.C. 20560, and is open every day of the year, 10 a.m. to 5:30 p.m., except December 25.

Under http://www.mnh.si.edu.nmnhweb.html you may find the National Museum of Natural History home page on the Internet.

—from National Museum of Natural History Smithsonian Institution, news release materials

BOOK REVIEW

by Robert M. Whelan, ECONorthwest, Portland, Oregon

GeoDestinies, by Walter L. Youngquist, 1997: National Book Company, P.O. Box 8795, Portland, OR 97207-8795, hardbound, 499 p., $29.95.

GeoDestinies discredits the widely held belief that "science will think of something" to solve the depletion of natural resources. In nontechnical terms, author Youngquist describes how world population growth will exhaust, in practical terms, many of the Earth's resources in the near future. He notes that "Geology, not economics, ultimately controls the availability of Earth resources."

Alarmist writings about the world running out of oil and other geological resources have cropped up periodically for more than a century now. Such predictions failed to consider the effects of new technologies, discoveries of additional reserves, substitution of materials, more recycling, and higher efficiencies. Consequently, rather than seeing the classic sign of shortages—prices rising faster than general inflation—we have seen declines in the prices of most mineral resources and those commodities, such as wheat, that use them (fertilizer, topsoil, groundwater). Youngquist discounts all this by noting that population growth is exponential and that science will no longer be able to keep up with the ever rising demands on resources.

Youngquist offers some compelling arguments. He emphasizes many of the geological and scientific realities often ignored by academics who rely too heavily on the belief that technology will protect us from shortages. He does an excellent job exploding popular myths about the environment, energy, and mineral resources. His book is written on a level that can be understood by someone with little background in science or economics.

It is clear, however, that he has very strong views stemming from his personal background working in the oil industry. Consequently, the book is not a balanced presentation. It places little weight on how changing prices and incomes can affect the allocation of scarce resources. Nonetheless, the book is thought provoking and, at times, entertaining to read. □

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