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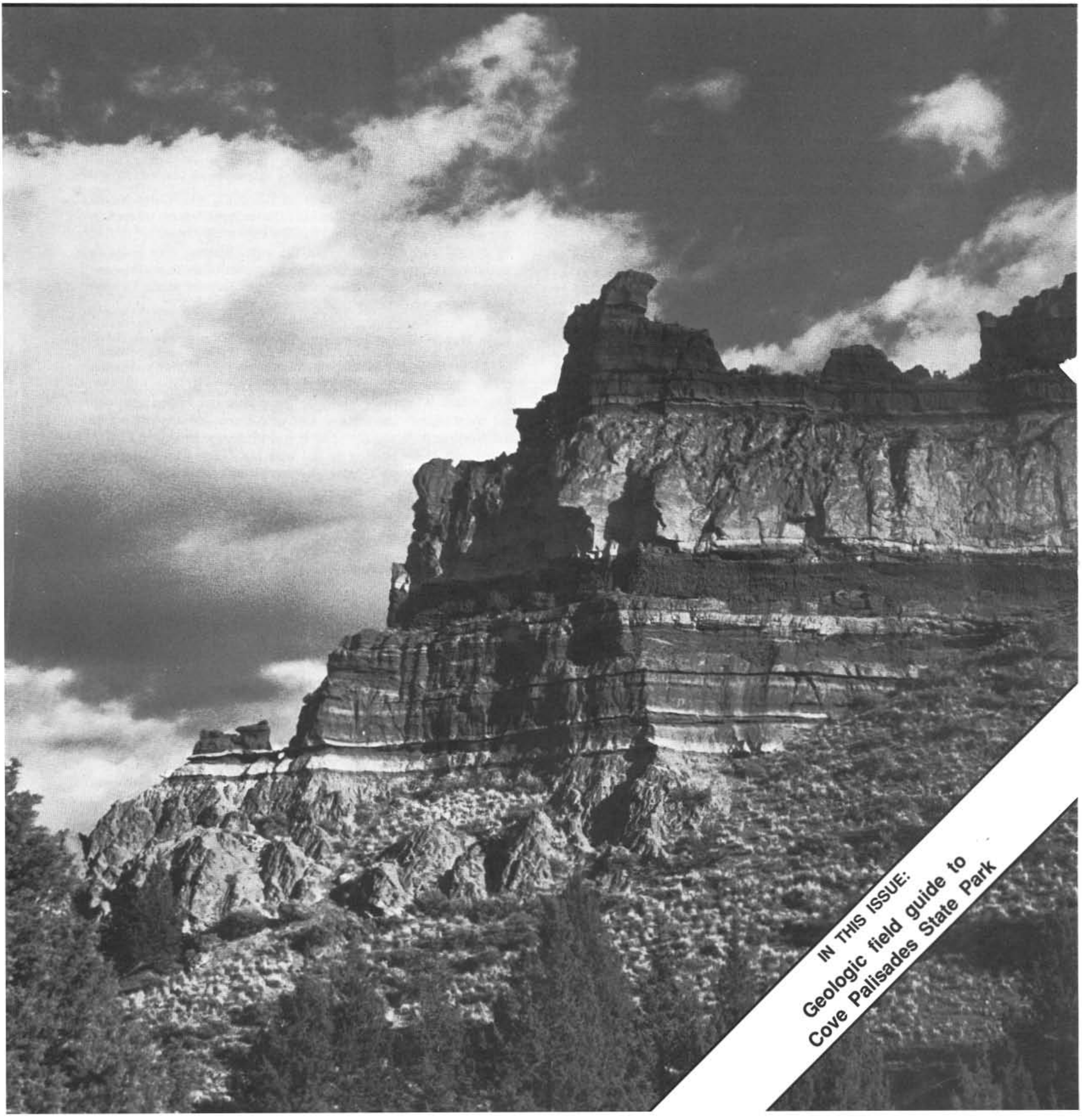

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Cove Palisades State Park

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The style to be followed is generally that of U.S. Geological Survey publications. (See the USGS manual *Suggestions to Authors*, 6th ed., 1978.) The bibliography should be limited to references cited. Authors are responsible for the accuracy of 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 DOGAMI.

Cover photo

"The Ship" at Cove Palisades State Park. Coarse sandstones and two ignimbrites are well displayed in this erosional remnant. The upper white ignimbrite is the Cove ignimbrite unit. The lower rough unit, just above the grass on the left, is the Jackson Buttes ignimbrite. The article beginning on the next page describes the geology of Cove Palisades State Park and is followed by a field trip guide to the area.

OIL AND GAS NEWS

Summary of 1989 drilling at Mist Gas Field

ARCO has finished drilling a seven-well program at Mist, completing three wells as gas producers and plugging four wells. The three new gas producers are the CER 41-16-64, CC 34-28-65, and CER 13-1-55 wells, drilled to depths of 2,105 ft, 2,240 ft, and 1,480 ft, respectively. The four abandoned wells are the CER 24-18-64, CC 34-8-75, Hamlin 33-17-65, and OR 34-25-66 wells, drilled to depths of 1,810 ft, 2,706 ft, 3,150 ft, and 2,452 ft, respectively.

DY Oil has drilled a six-well program at Mist, completing the Neverstill 33-30 as a gas producer. Total depth was 2,225 ft. The remaining five wells were plugged. These are the Burris CC-24-8, CER 23-22-64, Forest Cav 13-6, Lane CC-24-5, and Lane CC-24-5-A wells, drilled to depths of 2,684 ft, 2,680 ft, 1,796 ft, 1,473 ft, and 1,126 ft, respectively.

Rulemaking

Draft rules are being written on HB 2089, which was passed by the legislature this year. The bill calls for ground-water protection and surface reclamation when shallow exploratory holes are drilled by the oil and gas industry in the state. Seismic shot holes or shallow stratigraphic test holes are examples of these shallow exploratory holes. For details, contact Dan Wermiel at the Oregon Department of Geology and Mineral Industries.

Kyle Huber Award presented by NWPA

At its November meeting, the Northwest Petroleum Association (NWPA) presented the 1989 Kyle Huber Award to Duane Leavitt. The award is annually given to the persons or companies with the most significant achievement in oil and gas exploration in the Northwest during the year. It was presented to Duane Leavitt as a result of the drilling he did with DY Oil at Mist Gas Field, including a successful new gas completion.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth(ft)
434	ARCO Columbia Co. 13-3-55 36-009-00263	SW¼ sec. 3 T. 5 N., R. 5 W. Columbia County	Permitted; 1,655.
435	ARCO Columbia Co. 13-4-54 36-009-00264	SW¼ sec. 4 T. 5 N., R. 4 W. Columbia County	Permitted; 2,025.
436	ARCO CER 13-1-55 36-009-00265	SW¼ sec. 1 T. 5 N., R. 5 W. Columbia County	Permitted; 1,645.
437	ARCO OR 34-25-66 36-007-00022	SE¼ sec. 25 T. 6 N., R. 6 W. Clatsop County	Permitted; 2,280.
438	ONGD OR State 32-26 36-067-00004	NE¼ sec. 26 T. 1 S., R. 4 W. Washington County	Permitted; 2,000.
439	DY Oil Lane CC-24-5-A 36-009-00266	SE¼ sec. 5 T. 5 N., R. 5 W. Columbia County	Permitted; 2,000.

□

A field guide to the geology of Cove Palisades State Park and the Deschutes Basin in central Oregon

by Ellen Morris Bishop, Department of Geosciences, Oregon State University, Corvallis, Oregon 97331, and Gary A. Smith, Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

INTRODUCTION

The Deschutes River rises from unpretentious rivulets in the emerald meadows flanking Mount Bachelor. It meanders across the flat floor of the High Cascades and Newberry's lava plains. Then, fueled by melted snows and driven by 2,000 ft (600 m) of fall, it plunges northward, an awakened goliath, a river with a mission (Figure 1).

If it were not for the modern Deschutes River, we would know little of the basin that lies between the High Cascades and the venerable Blue Mountains. But because of the river, the rolling, juniper-clad expanse of west-central Oregon has become a storybook instead of remaining a mystery.

From Redmond to Gateway, the walls of the spectacular canyon of the Deschutes River reveal a basin periodically inundated by lava, swept by floods, and buried beneath volcanic ash. The river persistently cut its channel while eruptions and floods clogged its path to the sea. The Deschutes is a geologist's river. And one of the best places to witness its work is in the canyons of Cove Palisades State Park.

This relatively nontechnical guide to the geology of Cove Palisades State Park and the Deschutes Basin is based upon the work of coauthor Gary Smith, along with that of Richard Conrey, Gene Yogodzinski, Edward Taylor, and others who are cited herein. It updates and expands previously published

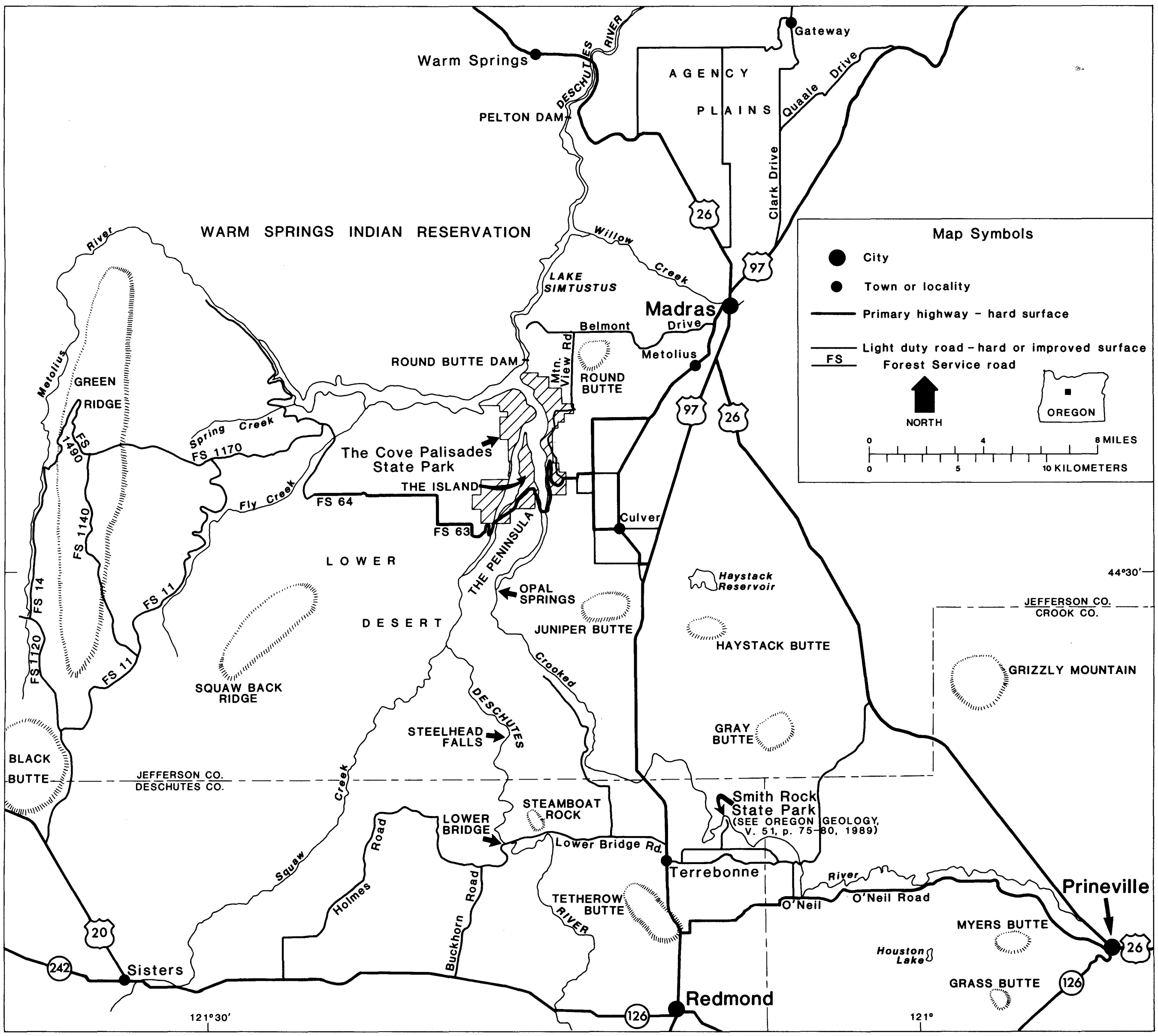


Figure 1. Map showing the geography of the Deschutes Basin.

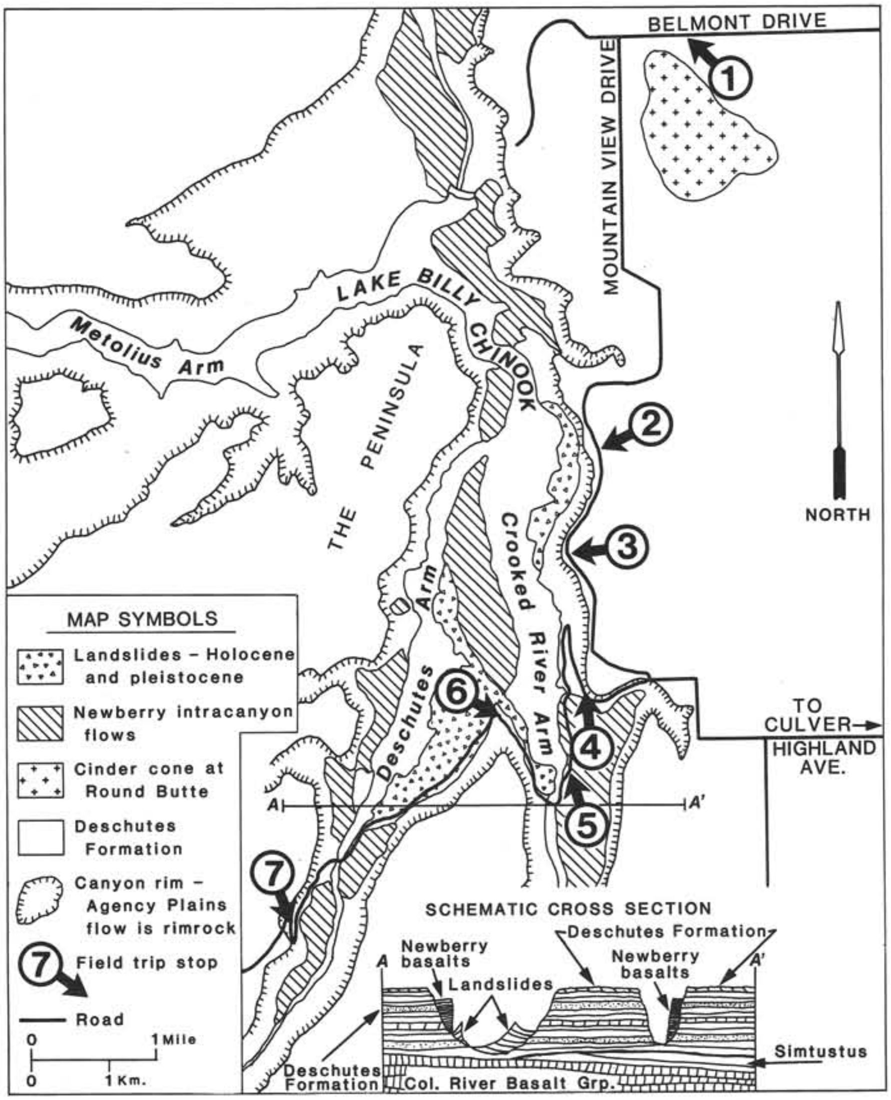


Figure 2. Map showing the geology of Cove Palisades State Park. Revised from Peterson and Groh (1970).

field guides (Peterson and Groh, 1970; Taylor and Smith, 1987). Most of the material printed in the regular format is for the lay reader who wants to learn about the area and its fascinating geology. However, additional and more technical information has been added in brackets for readers who want to learn more about the geologic details.

PRE-MIOCENE GEOLOGY OF THE DESCHUTES BASIN

The Deschutes Basin lies between the west-plunging nose of the Blue Mountains and the north-south Cascade arc (Figure 2). Its volcaniclastic rocks and flows cover approximately 1,900 mi^2 (5,000 km^2), extending approximately from Tumalo (9 mi [15 km] north of Bend) to Gateway (12 mi [20 km] north of Madras) in a crescent-shaped band approximately 15 mi (25 km) wide.

The nature of the basement beneath the Deschutes Basin is unknown. Feldspar-rich anorthosite clasts recovered from a Deschutes Formation basalt suggests that an accreted Precambrian greenstone terrane may underlie the Cascades, the Deschutes Basin, or both (Conrey, 1985).

Two Tertiary volcanic formations appear to extend from the Blue Mountains westward toward the Cascades beneath the Deschutes Basin. The Eocene Clarno Formation (52-40 million years [m.y.]) (Vance, 1988) consists primarily of calc-alkaline andesites, basaltic andesites, and minor rhyolitic domes, along with debris-flow deposits and other products of a stratovolcano terrane (Bishop, 1989b). These volcanic rocks extend from near Baker City in eastern Oregon along the axis of the Blue Mountain anticline to the east edge of the Deschutes Basin and in the Mutton Mountains.

The John Day Formation of Oligocene and early Miocene age is also present in the Deschutes Basin, principally as isolated buttes and highlands that punctuate the landscape. These include Juniper Butte, Powell Buttes, Cline Butte, Forked Horn Butte, and possibly Gray Butte.

Rhyolitic flows and ignimbrites of Oligocene age that are often correlated with the John Day volcanic rocks (Robinson, 1975) are exposed in Haystack Butte and Juniper Butte (Figure 3). Powell Butte, east of Redmond, is Oligocene in age and possibly a source of John Day tuffs. Cline Butte, to the west, is of similar composition and may be of similar age.

The best studied of these is Smith Rock and the Gray Butte complex just west of Terrebonne (Figure 4) (Obermiller, 1987; Bishop, 1989a). This bimodal volcanic center is associated with a thin veneer of olivine basalts dated at 18 m.y. (Obermiller, 1987) and a variety of younger rhyolitic volcanic rocks, ranging from the rhyolite of Gray Butte (12 m.y.) to the now-eroded tuff cone of Smith Rock (11.5 m.y.) (Obermiller, 1987). The age of the Gray Butte complex is uncertain. Stratigraphy (Smith, 1986a,b,c) and fossil evidence (Ashwill, 1983) indicate an Oligocene to early Miocene age and probable correlation with Powell Buttes and similar centers. Mapping by Robinson (1975) shows them to be older than the Columbia River basalts. However, studies indicate radiometric ages of

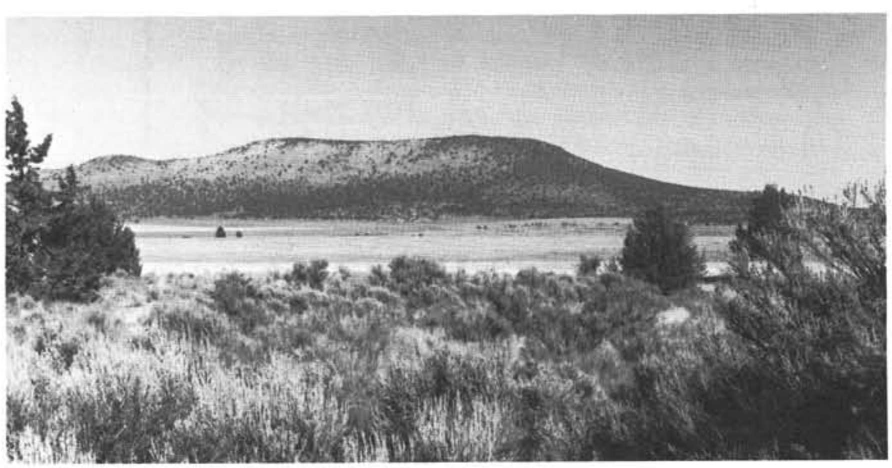


Figure 3. Juniper Butte is an inlier of the Clarno and John Day Formations.

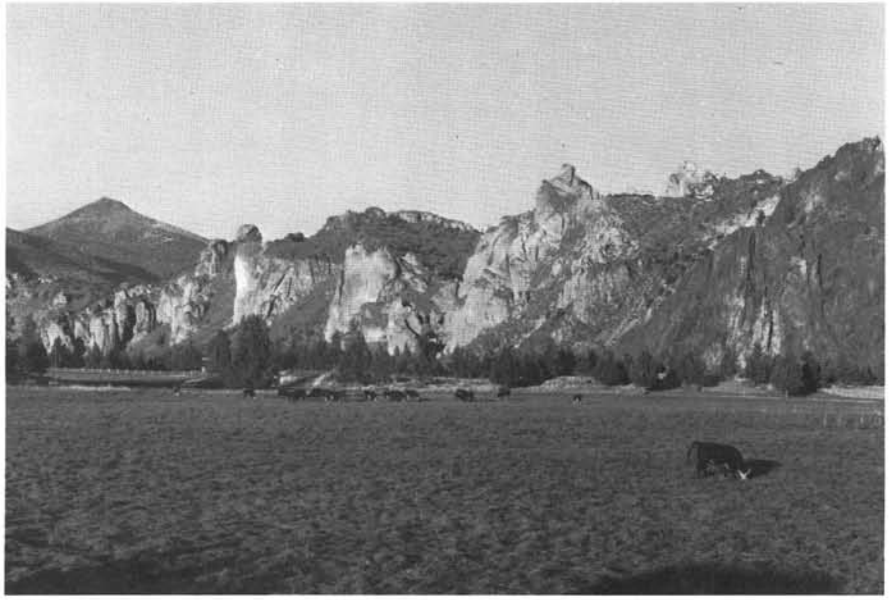


Figure 4. The Gray Butte complex from the west. High peak (left) is Gray Butte. Cliffs and outcrops to the right are Smith Rock. This eruptive center produced rhyolite and tuffs during a pause in the deposition of sediments into the Deschutes Basin.

12 m.y. for Gray Butte and 11.5 m.y. for the tuff of Smith Rock, suggesting a late Miocene age for these rocks (Obermiller, 1987).

SIMTUSTUS FORMATION

The story told by the colorful layers of rock in the canyon of the Deschutes River began about 15 m.y. ago at the time the basalts of the Columbia River Basalt Group were erupted in eastern Oregon, eastern Washington, and western Idaho. Basalt flows of the Prineville chemical type (high Ba and P_2O_5) (Uppuluri, 1974), which are part of the Columbia River Basalt Group, filled much of the channel of the river north of Willowdale (Smith, 1986a,b,c). The waters of the Deschutes slowed. Instead of rapidly downcutting, the river began to deposit more than it carried away, becoming a builder, an "aggrading" stream.

Our evidence comes from a sedimentary rock unit, the Simtustus Formation, that was deposited at the same time that Prineville-type Columbia River basalt flowed into the area from vents far to the south and east. The Simtustus Formation is a sequence of tan and gray, poorly consolidated gravels, sands, and silts exposed along Highway 97, 6 mi (10 km) northeast of Madras along grades into the small community of Gateway and also in the Deschutes River canyon along Lake Simtustus itself.

The Simtustus Formation extends over an area of at least 100 mi^2 (about 250 km^2) and is composed of volcaniclastic rocks conformable upon and interbedded with the Columbia River Basalt Group in the Deschutes Basin (Smith, 1986a). Its type section was defined from composite exposures on the east rim of Lake Simtustus. The formation varies from 3 to 200 ft (1 to 65 m) in thickness and is composed principally of tuffaceous sandstones, pebble conglomerates, debris-flow breccia, and rhyodacite ash-flow tuff.

[Sandstones and conglomerates of the Simtustus Formation]

[Cross-bedded volcaniclastic sandstones with subordinate mudstones are the most abundant rocks of the Simtustus Formation (Figure 5). They often become finer grained upward through a series of sandstone beds (fining-upward sequences). These poorly consolidated rocks represent point-bar, channel, and flood-plain deposits of a meandering river (Smith, 1986a).]

[Massive, tan-colored, fine-grained sandstones containing mudstones and layers of pumice clasts are less common than the coarse, cross-bedded sandstones. Graded bedding, where large clasts are on the bottom of a bed and grain size becomes smaller upward in the same bed, is common. In the Simtustus Formation, conglomerates generally consist of pebbles and cobbles set in a matrix of sand or mud (matrix-supported conglomerates) (Smith, 1986a) (Figure 6).]

[Depositional environment]

[The Simtustus Formation represents channel, overbank, and flood-plain deposition by a north-flowing river. Overall, this ancestral Deschutes River system aggraded, meaning that it deposited more than it eroded. This change of conditions was probably brought about by drainage disruption and filling in of the topography by flows of the Columbia River Basalt Group.]

[Age of the Simtustus Formation]

[The Simtustus Formation has been assigned a middle Miocene age (12 to 15.5 m.y.), based upon the middle Miocene Pelton flora reported by Ashwill (1983) and isotopic ages of the intercalated Columbia River basalts. The Simtustus Formation is separated from the Deschutes Formation by a subtle angular unconformity, indicating that the Simtustus was uplifted and eroded slightly before the Deschutes Formation was deposited on top of it (Smith, 1986a). Thus, there is approximately a 5-m.y. hiatus in deposition between the end of Simtustus deposition and the earliest deposition of the Deschutes Formation.]

Figure 5. Cross-bedded, coarse-grained sandstones of the Simtustus Formation are exposed in a roadcut southeast of Gateway. Photo is about 10 ft (3 m) across.

Figure 6. Matrix-supported, fine-grained sandstone and conglomerate of the Simtustus Formation is exposed at the base of the Gateway Grade.

THE DESCHUTES FORMATION

About 8 m.y. ago, the activity of volcanoes in the Cascades began to influence the basin of the Deschutes River. An increasing amount of volcanic debris clogged the drainage of the river, transforming the Deschutes again into a depositing, aggrading system.

Most of the multicolored sands and volcanic flows that now form the layer-cake walls of the canyon of the Deschutes River were deposited from about 8 until about 4 m.y ago (Figure 7).

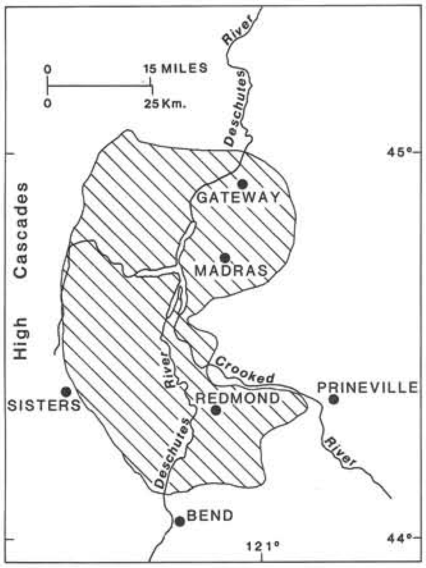


Figure 7. Map showing the distribution of the Deschutes Formation. After Smith (1986a).

These rocks are now known as the Deschutes Formation. Basalt flows, ash-flow tuffs called "ignimbrites" (hot ash and gas that consolidate into a sometimes-hard, sometimes-crumbly layer of pumice), as well as flood-generated torrents of sand and gravel, all contributed to the river's burden—and the geologic record left as the river's storybook (Figure 8). The formation has a maximum thickness of 2,300 ft (700 m).

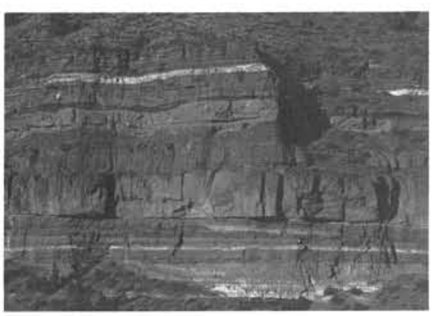


Figure 8. Interbedded sandstones, debris flows, ignimbrites, and basalts are typical of the mixed stratigraphy of the Deschutes Formation. This 100-ft (30-m)-high exposure along the Deschutes River is on the east side of Steelhead Falls.

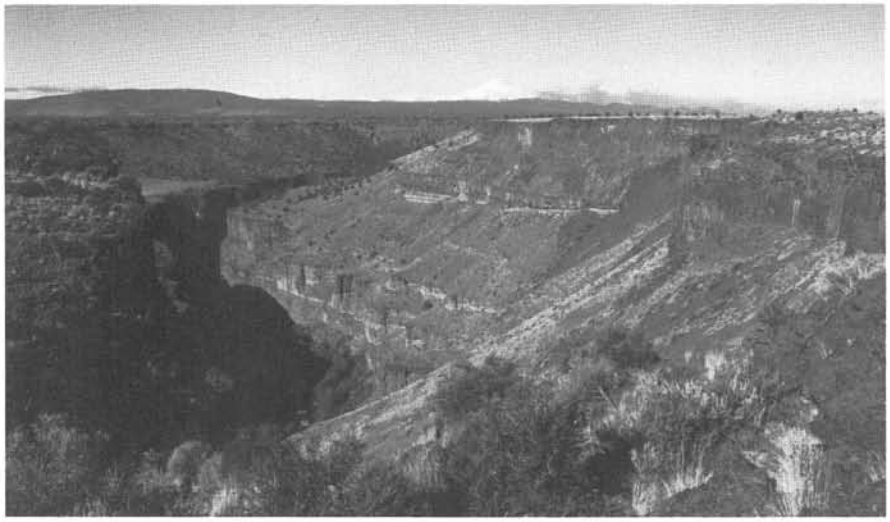


Figure 9. Narrow canyon of the Crooked River near Opal Springs west of Culver is incised through the Deschutes Formation. Squaw Back Ridge, a 2.9-m.y.-old shield volcano forms a bump on the skyline to the left. Green Ridge is the low, dark feature beneath Mount Jefferson in the far background.

Most volcanic sources for the Deschutes Formation were located in the Cascade Range, although subordinate amounts of lava and ash were extruded from vents in the central and eastern parts of the basin. In general, the volcanic rocks (both flows and ignimbrites) thicken and become more abundant westward, forming virtually the entire section at Green Ridge (Conrey, 1985) and the eastern buttress of Mount Jefferson (Yogodzinski, 1986) (Figure 9). Ignimbrites are well preserved and most common in the center of the basin. Sediments increase in thickness and are finer grained eastward through the Deschutes Formation.

BASALTS OF THE DESCHUTES FORMATION

Many of the hard, black basalt flows now exposed in the walls of the Deschutes River canyon were erupted from the eastern edge of the Cascades from low-lying, gently-sloping basaltic shield volcanoes east of where Mount Jefferson was to appear some 7 m.y. later (Figure 9). Others were erupted from vents within the Deschutes Basin, most notably from Tetherow Butte and Round Butte. More rarely, vents developed in the east part of the basin, where, 6.4 m.y. ago, they spread from shield volcanoes near Grizzly northward along Willow and Hay Creeks.

[Cascade diktytaxitic basalts]

[The most abundant basalts within the Deschutes Formation flowed eastward from the nascent Cascades, including the low-lying vents of Green Ridge. Most are olivine basalts with diktytaxitic textures, containing numerous small vesicles that are rimmed with microscopic crystals (Figure 10). These basalts produced distinctive features such as pipe vesicles (Figure 11) when flows encountered water or damp ground.]

[Geochemically, most Deschutes Formation basalts are high-alumina olivine tholeiites with no distinctive geochemical hallmark of their tectonic setting. They are similar to some High Cascade basalts, containing about 16.5 weight percent Al_2O_3, with SiO_2 varying between 49 and 52 weight percent (Table 1) (Smith, 1986a).]

[Deschutes Basin porphyritic basalts]

[Basalts with textures other than diktytaxitic comprise almost half the basalts of the Deschutes Basin. A few occur near the top of Green Ridge (Conrey, 1985). Voluminous lavas that contain visible crystals of pyroxene and plagioclase were erupted from Tetherow Butte. Olivine-bearing basalts are characteristic of Round Butte. The porphyritic basalts are slightly alkaline in character, with lower silica and higher titanium and zirconium contents than the diktytaxitic lavas that were erupted from the Cascades (Table 1) (Conrey, 1985; Smith, 1986a).]

[The basalts erupted from Tetherow Butte are the most evolved of the Deschutes Basin lavas. They are also enriched in Ba, K, Rb, Sr, Zr, and Y compared to the diktytaxitic basalts that were erupted from the eastern Cascades (Smith, 1986a).]

Figure 10. Photomicrograph of diktytaxitic basalt. Note rectangular, lathlike plagioclase crystals protruding into cavities. Photo courtesy of Marvin Beeson.

Figure 11. Pipe vesicles in the Big Canyon Flow, Grandview Grade, Cove Palisades State Park.

Figure 12. Pelton basalt, the oldest diktytaxitic basalt in the Deschutes Formation. This view is at the crest of Clark Drive near Gateway.

DISTINCTIVE BASALTS OF THE DESCHUTES FORMATION

Because of texture, areal extent, stratigraphic location, or exposure, some basalt flows of the Deschutes Formation are distinctive and are useful as marker beds. Several of these flows are described below. Their geochemistry is summarized in Table 1.

Pelton basalts

The oldest known flows in the Deschutes Formation are the Pelton basalts, dated at 7.6 m.y. They extend northward from Lake Billy Chinook and Round Butte Dam to Pelton Dam and Gateway. They are well exposed and perhaps most accessible at the crest of Clark Drive leading down into the community of Gateway (Figure 12). To the south, near Round Butte Dam, as many as eight flows have been reported in this unit (Jay, 1982). The Pelton basalt is a diktytaxitic olivine basalt with comparatively low alumina content (15.7 weight percent). This geochemical fingerprint, coupled with the marked thinning of the unit to the north, suggests a source in the southeastern Deschutes Basin, where similar basalts are more abundant.

Table 1. *Geochemistry of Deschutes Formation basalts. All values are in weight percent.*

	Diktytaxitic basalts			Phenocrystic basalts		
	J203	**OC2**	**D299**	**RB46**	**SF143**	**RB39**
SiO_2	50.3	50.5	51.1	50.9	52.2	52.4
TiO_2	1.8	1.6	1.0	2.6	2.7	1.8
Al_2O_3	16.1	16.3	17.0	14.6	13.7	16.8
FeO	11.5	9.9	8.0	14.0	14.0	9.2
MnO	0.2	0.2	0.2	0.3	0.2	0.2
MgO	7.5	8.2	8.0	4.6	5.1	5.9
CaO	9.5	11.1	10.8	8.6	7.5	8.8
Na_2O	2.4	2.6	2.3	3.1	3.7	2.1
K_2O	0.4	0.3	0.2	0.6	0.7	1.0
P_2O_5	0.4	0.3	0.2	0.6	0.5	0.4
TOTAL	100.0	100.8	98.7	100.2	100.3	98.6
Ba	402	na	91	467	484	456
Rb	22	na	9	19	22	19
Sr	320	na	337	372	386	805
Zr	113	na	89	157	155	213
Ni	112	na	110	22	38	140

J203=Pelton basalt; OC2=Opal Springs basalt; D299=Fly Lake flow; RB46=Agency Plains flow, Tetherow Butte basalt; RB39=Round Butte.. Analyses adapted from Smith, 1986a.

Tetherow Butte basalts

Radiometrically dated at 5.31 m.y. (Smith, 1986c), these extensive and voluminous porphyritic basalts that were erupted from Tetherow Butte near Terrebonne flowed northward almost to Gateway. There are two distinctive flows and an abundance of more locally derived eruptive products. Tetherow Butte is a 3-mi (5-km)-long complex of red and black cinder cones southwest of Terrebonne (Figure 13). The original height of these cones may have approached 660 ft (200 m).

The most extensive flow from this complex is named the Agency Plains flow (Figure

Figure 13. Pahoehoe flow structures in the Tetherow Butte flows. Tetherow Butte, southwest of Terrebonne, was the source of basalts that flowed approximately 36 mi (60 km) northward to Agency Plains.

Figure 14. Gateway valley, looking northward to the Deschutes. Agency Plains basalt forms the rimrock to left; the older Pelton basalt forms rim to right.

rhyolite lavas are subordinate in volume and breadth of distribution to the basalts of the Deschutes Formation. None of these units have been distinguished by name. They increase dramatically in abundance westward toward Green Ridge and Mount Jefferson. Notable occurrences are along Green Ridge (all lithologies), at Pipp Spring on the Warm Springs Indian Reservation (basaltic andesite), and a distinctive, columnar-jointed basaltic andesite just below the rim on the Crooked River grade near the entrance to Cove Palisades State Park (Figure 16) (Smith, 1986a).

These seemingly more evolved rocks are apparently unrelated to the abundant diktytaxitic basalts of the Deschutes Formation. They cannot be derived from diktytaxitic basalts by simple fractionation. They may have come from a different source (Smith, 1986a) or have been produced by the mixing of a silica-rich (rhyolite) magma with a basalt (Conrey, 1985).

Figure 16. Deschutes Formation basaltic andesite in the roadcut near the east entrance to Cove Palisades State Park displays well-defined columnar jointing. The rounded base of this flow and the gravels beneath it suggest that the flow followed a small

14) (Smith, 1986a). It can be traced from Tetherow Butte northward past Madras and covers most of the flat farmland known as Agency Plains between Madras and Gateway. This flow, which varies in thickness from 7 to 165 ft (2 to 50 m), forms part of the east rimrock at Cove Palisades and occurs along much of the central Deschutes River canyon.

A slightly younger flow, named the Crooked River flow (Smith, 1986a), extends northward to Opal Springs, where its flow front forms a 7-ft (2-m)-high escarpment on the canyon rim. Low spatter mounds are aligned on the top of this flow, perhaps tracing an ancestral Crooked River drainage (Smith, 1986a,b,c).

Round Butte basalts

The last basaltic lavas erupted in the Deschutes Basin were extruded 3.97 m.y. ago from Round Butte, 5 mi (8 km) southwest of Madras (Smith, 1986c) (Figure 15). One flow can be traced northward toward Agency Plains; the lowest of four flows that extend westward toward Round Butte Dam displays pillow structures and peperites where it entered the channel of the ancestral Deschutes River (Smith, 1986a). Other flows of undetermined thickness apron the remainder of the butte.

OTHER FLOW ROCKS OF THE DESCHUTES FORMATION

Basaltic andesite, andesite, dacite, and

Figure 15. Round Butte is a cinder cone perched atop the shield volcano that erupted the youngest flows of the Deschutes Formation. Note ancient landslide in middle ground.

IGNIMBRITES OF THE DESCHUTES FORMATION

In addition to producing basalts, the vents of the ancestral Cascades erupted hot, frothy clouds of ash (called "ignimbrites") into the Deschutes Basin. Red and pink, salmon, white, or gray, the colored layers in the canyon walls are mostly ignimbrites. These porous, silica-rich ash units are abundant in the Deschutes Formation. Ignimbrites are known by a number of other names, including "ash-flow tuff" and "welded tuff." All apply to a hot, laterally-ejected, ground-hugging cloud of ash and gas that may travel at velocities of up to 75 mph (120 km/hr) and may consist of several pulses of ash that are deposited in the same area and that cool as a single unit.

The ignimbrites of the Deschutes Formation are commonly 7 to 33 ft (2 to 10 m) thick. Most were extruded from shallow magma chambers beneath now-buried vents in the Cascades. They are interbedded with the lava flows and sedimentary units of the Deschutes Formation. There is no apparent systematic variation in their abundance or composition upward through the section.

Ignimbrite textures

There is a tremendous variety of texture, content, and consolidation in the ignimbrite units of the Deschutes Formation. They may contain a variety of components, including pumice clasts, rock clasts, and pebbles or cobbles of underlying units. They may be densely welded into a glassy, columnar-jointed, flow-like mass, if the unit was deposited at temperatures high enough to allow molten ash to stick together. Such units may contain flattened, elongate and glassy clasts, termed "fiamme," that result from the collapse and quick cooling of frothy, molten pumice clasts (Figure 17).

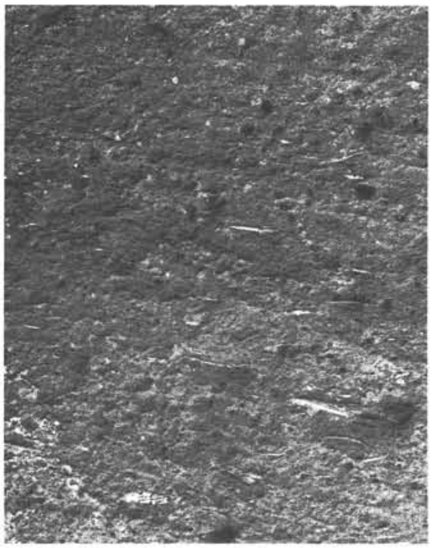


Figure 17. The thin white clasts in this ignimbrite are flattened pumice clasts called "fiamme." Their presence indicates that the ash flow was deposited at relatively high temperatures. (This photo is of the Rattlesnake ignimbrite and was taken east of Dayville, Oregon. The Rattlesnake ignimbrite is a widespread ash-flow tuff that is contemporaneous with the Deschutes Formation and is found over an area from south of Burns to the Deschutes Basin.)

These textures usually develop in the centers of large ash-flow sheets that cover hundreds of square miles, rather than in smaller ignimbrites covering tens of square miles that seem to be common in the Deschutes Formation. Ignimbrites like those of the Deschutes Formation are more characteristically dusty, fragile, and crumbly masses of tuff, small in volume, that came to rest far from their vent. They may at first resemble mudflow deposits. However, examination will reveal that many clasts are pumice, usually of only one or possibly two different compositions (Figure 18).

Ignimbrite stratigraphy

There is a stratigraphy to most ignimbrites, a sort of anatomical classification

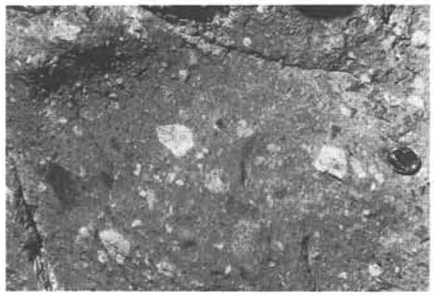


Figure 18. Mixed basalt and rhyodacite clasts in an unnamed ignimbrite at Cove Palisades State Park.

scheme. There are three parts to most ignimbrites of the Deschutes Basin (Figure 19): (1) A thinly laminated, poorly consolidated layer of ash or pumice at the base of the ignimbrite caused by the initial contact of the base of the unit with the cold ground. This unit is formed into thin beds (laminations) by the powerful initial surge of the rapidly moving ignimbrite. (2) The bulk of the ash flow is a matrix-supported, poorly sorted pyroclastic conglomerate, usually containing pumice clasts. This is the thickest portion of the ash flow. The bottom portion of this layer may be graded, from large clasts just above layer 1, upward to finer material. Above this normal grading, pumice clasts may be reversely graded. (3) The tops of some ignimbrites are veneered by layers of ash, presumably the last dregs of the ash cloud to settle.

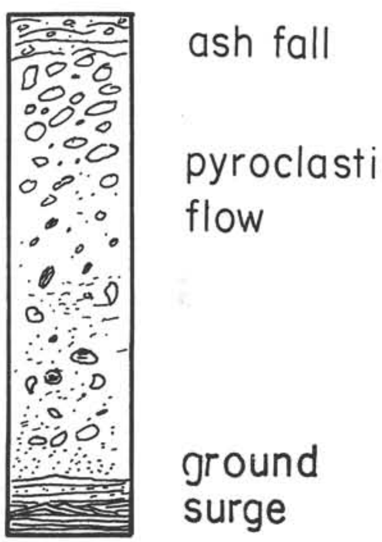


Figure 19. An ignimbrite section, typical of those in the Deschutes Formation. After Sparks and others (1973).

[Composition and petrology of Deschutes Formation ignimbrites]

[The ignimbrites of the Deschutes Formation are mostly dacitic to rhyolitic in composition (Table 2), with silica contents ranging from about 62 to 72 weight percent. Only one unit of basaltic andesite composition was reported by Smith (1986a).]

[Some ignimbrites contain two or more varieties of pumice clasts—probably the result of mixing two different magmas just prior to ignimbrite eruption (Conrey, 1985) or eruption from a zoned magma chamber (Smith, 1986a).]

[Modeling has shown that these dacitic to rhyolitic ash flows were not derived from the olivine basalts by fractionation. Rather, most had a separate source or underwent a mixing process to arrive at their erupted compositions (Conrey, 1985; Smith, 1986a).]

Table 2. *Geochemistry of Deschutes Basin ignimbrites. All values are in weight percent.*

	SJ19	RB10	RB27
SiO_2	71.6	70.4	62.4
TiO_2	0.5	0.5	1.3
Al_2O_3	15.7	15.7	17.0
FeO	3.4	3.0	5.8
MgO	2.0	0.8	2.1
CaO	2.4	1.6	4.3
Na_2O	2.1	4.3	4.7
K_2O	2.5	4.0	1.6
TOTAL	100.1	100.4	99.1

SJ19=Chinook ignimbrite; RB10=Cove ignimbrite; RB27=Peninsula ignimbrite. All analyses adapted from Smith, 1986a.

DISTINCTIVE IGNIMBRITE UNITS IN THE DESCHUTES FORMATION

Of the hundreds of ignimbrites within the Deschutes Formation, several merit more detailed description because they are well exposed, contain characteristic features, and/or are useful as stratigraphic markers. Although none of the units described below have been radiometrically dated, they are discussed in order of age, from oldest to youngest.

Jackson Buttes ignimbrite

The lower, pink-colored slope of "The Ship" at Cove Palisades State Park is composed of a poorly welded unit known as the Jackson Buttes ignimbrite (cover photo). It is named for its exposure at Jackson Buttes on the Warm Springs Indian Reservation. It is as much as 76 ft (23 m) thick, and, in some locations, displays columnar jointing. The pinkish to light-orange color of this unit is due to alteration by escaping gases during its deposition and consolidation.

Cove ignimbrite

At Cove Palisades State Park, the Cove ignimbrite is a white tuff that forms the prow of "The Ship" and is also found in the roadcuts along the access roads (Figure 20). It is unwelded and contains scattered white to light-gray pumice clasts up to 0.8 in. (2 cm) in diameter. This unit, which has a very

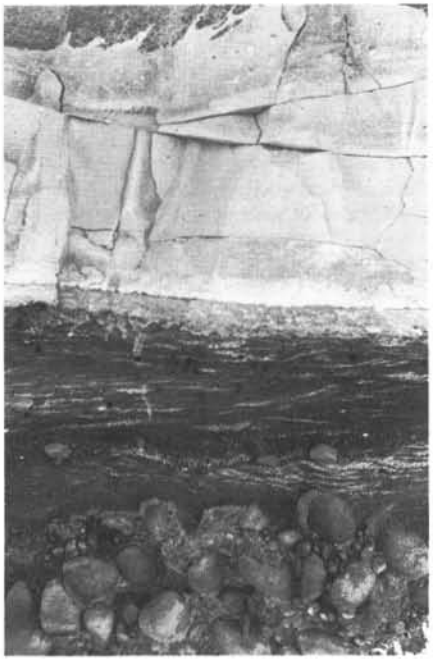


Figure 20. The Cove ignimbrite, about 2 ft (0.6 m) in thickness here, is exposed in roadcut on the Crooked River grade. Note flat, layered bottom above conglomerate and sandstone. Uneven top suggests that a debris flow covered the ignimbrite here before it was well consolidated.

limited distribution, is exposed only over about 5 mi (8 km) of the Deschutes River canyon.

Fly Creek ignimbrite

This unit is distinctive because it is the most mafic of ignimbrites analyzed from the Deschutes Basin (approximately 53 weight percent silica) (Conrey and Dill analyses, *in* Smith, 1986a) and is also one of the most densely welded ignimbrites in the basin, a fact consistent with its probable higher temperature of eruption and large lateral distribution (more than 68 mi^2 [175 km^2]) (Smith, 1986a). In Cove Palisades State Park, this unit is about 33 ft (10 m) thick and unwelded, light orange in color, with gray to light-orange pumice clasts. Its clasts are of at least two different compositions: rhyodacite and basaltic to basaltic-andesite pumice. The Fly Creek ignimbrite thickens dramatically westward, where it becomes densely welded and glassy in exposures along Fly Creek.

SEDIMENTARY UNITS OF THE DESCHUTES FORMATION

Records of floods and braided river channels are present in the poorly consolidated conglomerates and sandstones exposed along the canyon of the Deschutes River. Some deposits, such as the Tetherow debris flow near Tetherow Crossing on the Deschutes, contain enormous boulders up to 40 ft (12 m) in diameter, indicating sudden, catastrophic avalanches of debris unleashed from now-eroded Cascade volcanoes. Others, more common and less dramatic, are the remains of turbulent floods of gravels and sand.

[Sedimentary environments]

[The poorly cemented sedimentary rocks of the Deschutes Formation consist generally of clast-supported conglomerates and volcaniclastic sandstones. They may be subdivided into five facies associations, or sedimentary environments (Smith, 1986b).]

[River-channel deposits]

[Clast-supported conglomerates, with pebbles and cobbles that rest upon one another, rather than lying in a matrix of mud and sand, are deposits of an active river channel (Figure 21). Clasts are usually rounded pebbles and cobbles laid like shingles parallel and facing upstream in a pattern called "imbrication." Sandstone interbeds may represent channel bars or smaller channels abandoned after periods of high discharge (Smith, 1986a). Such conglomerates are abundant, thick, and striking in the Deschutes Formation (Figure 22).]

[Flood-plain deposits]

[Massive or laminated fine-grained sandstones and siltstones are characteristic of flood-plain deposits. These rocks are comparatively rare in the Deschutes Formation. Where present, they commonly contain fossil floras (including *Planus*, *Populus*, *Acer*, and *Salix*) (Ashwill, 1983). Diatomite and diatomaceous mudstone deposits, usually less than 3 ft (1 m) thick, indicate the presence of marshes and small, acidic lakes.]

[Sheet-flood deposits]

[Thinly bedded sandstone and pebble conglomerates 2 to 10 in. (5 to 25 cm) thick that may display limited, low-angle cross-bedding are typical of deposition by slow streams in broad, shallow, braided channels (Figure 23). Such deposits are common in the Deschutes Formation.]

[Hyperconcentrated flood-flow deposits]

[Normally graded, clast-supported conglomerates or coarse sandstones are typical of fluid, turbulent mudflows or flood deposits. These types of sedimentary processes have been named "hyperconcentrated flood flows" (Smith, 1986b).

Figure 21. Imbricated, clast-supported cobble conglomerates of the Deschutes Formation represent river-channel deposits.

Figure 22. This thick section of river-channel conglomerates fines upward and is overlain by sands of smaller channels and flood-plain deposits. Such a sequence suggests that an active river cut a channel here, then migrated or meandered laterally, leaving flood-plain deposits on top of its old channel.

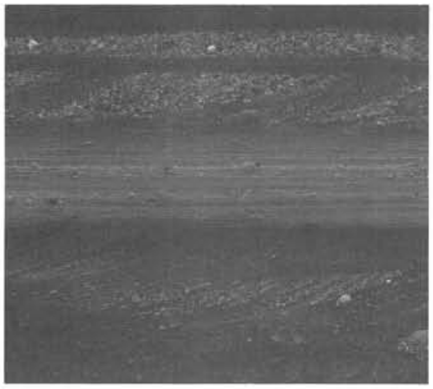


Figure 23. Sheet-flood deposits in the dark sands of the Deschutes Formation display low-angle cross-bedding and matrix-supported pebble conglomerates.

They develop when a high discharge of water carries a sediment load intermediate between a debris flow and normal stream flow. Such a "hyperconcentrated flood flow" would contain between 40 and 80 weight percent as sediment and the remainder as fluid (water). Such flows would be turbulent, and grain-on-grain support would be important for the transportation and continued suspension of particles. These flows are more fluid than debris flows or lahars. They are abundant in the Deschutes Formation.]

[Two principal types of sediments result from hyperconcentrated flood flows. The first is a clast-supported, normally graded conglomerate (Figure 24). These rocks may grade upward into horizontal bedding. The second, in lower velocity flows, is a thinly bedded, coarse sandstone that displays a wide range of clast size (poor sorting) and usually grades continuously into the beds below and above.]

[Debris-flow deposits]

[Unsorted, usually very coarse-grained, matrix-supported deposits that were transported at high rock/water ratios are termed "debris flows" (Figure 25). This term encompasses fluvial, mudflow-type deposits as well as flows more closely linked to volcanism (lahars).

Some of these units within the Deschutes Formation, such as the Tetherow debris flow, are spectacular, containing clasts more than 6 ft (1.8 m) in diameter. Many grade laterally into finer grained rocks. Debris-flow deposits are increasingly rare toward the east in the Deschutes Formation.]

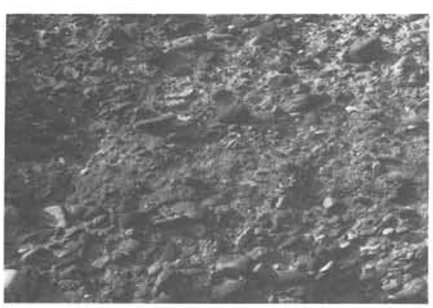


Figure 24. Hyperconcentrated flow, clast-supported, normally-graded conglomerate, Deschutes Formation, Cove Palisades State Park.

Figure 25. Debris-flow deposit, Deschutes Formation, near Steelhead Falls.

PLIOCENE VOLCANISM IN THE DESCHUTES BASIN

What stopped this deposition and returned the Deschutes to its canyon-cutting glory was, literally, the downfall of the Cascades. For reasons not fully understood, about 4 m.y. ago, the volcanoes of Oregon began to subside into a downfaulted structure called the High Cascade graben (Figure 26). Eruptive activity remained vigorous, although perhaps not as explosive as before. However, because the rising east wall of the graben formed a barrier to eastward transport of volcanic debris, products of the late Pliocene eruptions were trapped in the graben and never reached the Deschutes drainage.

Because little of the river's energy was needed to carry debris erupted from these sinking volcanoes, the Deschutes could now go to work downcutting and exposing its history.

Several volcanic centers to the southeast—most notably Grass Butte near Prineville—erupted diktytaxitic basalts that flowed mostly westward into the Deschutes Basin. Basalts from these low shield volcanoes form the rimrock at Terrebonne and much of the high, rock-strewn plateau between Redmond, Terrebonne, Powell Butte, and Prineville. The age of these flows is 3.4 m.y. (Smith, 1986a). Pleistocene basalts also cover much of the area between Redmond and Prineville.

East of the High Cascade graben, relatively small quantities of basalts were erupted, forming low shield volcanoes or cinder cones. Squawback Ridge and Little Squaw Back, east of Green Ridge, are 2.9-m.y.-old shield volcanoes built by these eruptions.

Two million years ago, the Deschutes River drained northward along a channel similar in location to the canyons we see today. The course of the old river cut through a semiarid plain, incising a canyon through the volcanic layer cake. By 2 m.y. ago, the canyons were nearly as deep as we see them today.

PLEISTOCENE INTRACANYON BASALTS

Intracanyon basalt flows from Newberry volcano and the rising Cascades flowed through and filled the Deschutes, Metolius, and Crooked River channels from 1.6 million to less than 700,000 years ago.

The most voluminous of these intracanyon flows, dated at about 1.2 m.y., came from the vicinity of Newberry volcano and followed the Crooked River canyon from O'Neil northward to the present location of Round Butte Dam (Smith, 1986a). At least 15 of these intracanyon flows were erupted in rapid succession. They form the distinctive intracanyon bench that extends along the Crooked River from the approximate location of Smith Rock State Park northward through Cove Palisades State Park (Figure 27). These basalts also form "The Island," a stark, flat-

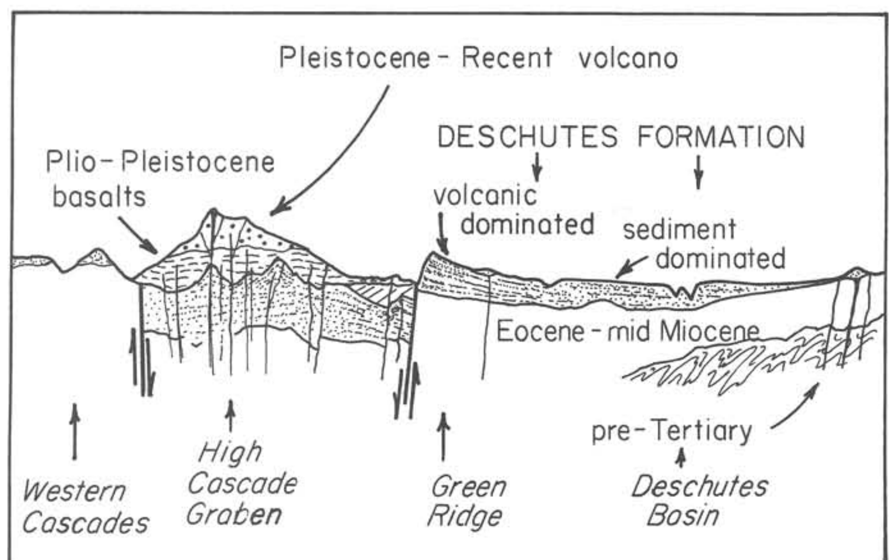


Figure 26. Schematic cross-section of the Cascades and the Deschutes Basin. After Smith (1986a) and Taylor and Smith (1987).

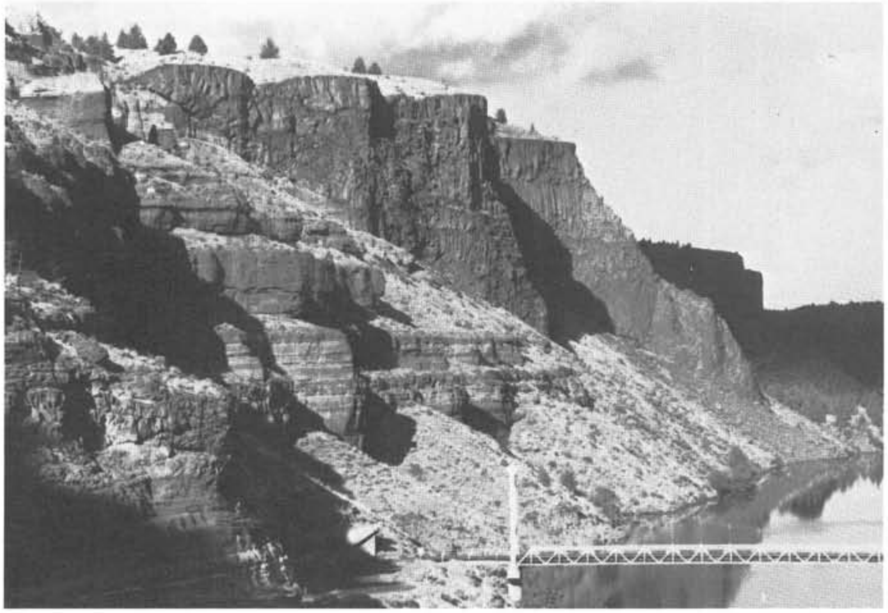


Figure 27. Intracanyon basalts from Newberry volcano lap onto and overlie the horizontal beds of the Deschutes Formation in Cove Palisades State Park. The contact between the two units cuts diagonally from near the top left of the photo down toward the lower right. View is on the west side of the Deschutes Arm of Lake Billy Chinook.

topped basalt ridge that rises abruptly from Lake Billy Chinook, separating the Deschutes from the Crooked River in Cove Palisades State Park.

The extreme thickness of the Newberry basalts at Cove Palisades suggests that they may have ponded in that area of the canyon, perhaps due to the solidification of a basalt dam somewhere downriver. Such ponding might also account for the fact that basalts flowed from Cove Palisades more than 2.5 mi (4 km) up the Deschutes River canyon.

The Newberry basalts are distinctive, cliff-forming rocks in Cove Palisades State Park and elsewhere along their exposure in the canyons. They were evidently extruded rapidly; multiple flows form single cooling units. These abrupt cliffs provide excellent displays of columnar jointing, with lower colonnades of regular, parallel columns, and upper entablatures composed of tiers of curving and discontinuous columns or sequences of colonnade-entablature-colonnade (Figure 28).

The difference in structure of these two portions of a basalt flow has been correlated with differences in cooling history (Long and Wood, 1986). Colonnade columns form during slow, steady-paced, downward cooling. The more wildly creative entablature structures result from local variations in cooling rate and direction.

CONCLUSION

The Deschutes Basin is a record book of more than 15 m.y. and 2,800 ft (900 m) of volcanic deposition and erosion. Among the noteworthy observations that can be made about this area are the persistence of a river system in the same valley for a long time, the large volumes of lava and ash erupted into the Deschutes Basin during the late Miocene and early Pliocene, and the variety of sand and gravel deposits laid down in this filling basin.

REFERENCES CITED

Ashwill, M., 1983, Seven fossil floras in the rain shadow of the Cascade Mountains: Oregon Geology, v. 45, p. 107-111.

Bishop, E.M., 1989a, Smith Rock and the Gray Butte complex: Oregon Geology, v. 51, p. 75-80.

———1989b, Preliminary report on the petrology of the Clarno Formation, central and eastern Oregon, *in* Moye, F., ed., The Eocene of the Pacific Northwest: Geological Society of America Special Paper, in press.

Cavendar, T.M., and Miller, R.R., 1973, *Smilodonicthys rastrous*, a new Pliocene salmonoid fish from the western United States: University of Oregon Museum of Natural History Bulletin 18, 44 p.

Conrey, R.M., 1985, Volcanic stratigraphy of the Deschutes Formation, Green Ridge to Fly Creek, north-central Oregon: Corvallis, Oreg., Oregon State University master's thesis, 349 p.

Hammond, P.E., 1989, Guide to the geology of the Cascade Range: American Geophysical Union Field Trip Guidebook T306, 215 p.

Jay, J.B., 1982, The geology and stratigraphy of the Tertiary volcanic and volcaniclastic rocks, with special emphasis on the Deschutes Formation, from Lake Simtustus to Madras in central Oregon: Corvallis, Oreg., Oregon State University master's thesis, 119 p.

Long, P.E., and Wood, B.J., 1986, Structures, textures, and cooling histories of Columbia River basalt flows: Geological Society of America Bulletin, v. 97, p. 1144-1155.

Obermiller, W.A., 1987, Geologic, structural, and geochemical features of basaltic and rhyolitic volcanic rocks of the Smith Rock/Gray Butte area, central Oregon: Eugene, Oreg., University of Oregon master's thesis, 169 p.

Peterson, N.V., and Groh, E.A., 1970, Geologic tour of Cove Palisades State Park near Madras, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 32, p. 141-168.

Robinson, P.T., 1975, Reconnaissance geologic map of the John Day Formation in the southeastern part of the Blue Mountains and adjacent areas, north-central Oregon: U.S. Geological Survey Miscellaneous Investigations Series Map I-872.

(Continued on page 16, ***References****)*

Figure 28. Intracanyon bench of Newberry basalts in the Deschutes River canyon near Steelhead Falls.

Field trip guide to Cove Palisades State Park and the Deschutes Basin

by Ellen Morris Bishop, Department of Geosciences, Oregon State University

INTRODUCTION

This field trip guide is designed to help the user examine and understand the varied rocks of Cove Palisades State Park. Interesting side trips may also be taken to other areas in the Deschutes Basin that are shown on the map (Figure 1).

One of the most spectacular and accessible cross-sections of the Deschutes Formation is exposed in Cove Palisades State Park. Therefore, this field trip guide focuses on the single road that descends into the canyon at Cove Palisades, where the Deschutes Formation and intracanyon Newberry basalts are well exposed. Several large landslides, and one much smaller, very recent one, are also present in the canyon.

This field trip may be easily negotiated in a single day. The history and facilities of Cove Palisades Park are detailed elsewhere in this guide. Because the park has well-developed campgrounds and a small store, it may readily be used as an overnight stop on a longer tour of Pacific Northwest geology.

COVE PALISADES STATE PARK FIELD TRIP GUIDE

Mile 0.0. Begin field trip at City Hall located at the intersection of D and 6th Streets in downtown Madras. Follow D street west across Highway 97 to the old Culver Highway. Bear left (south) toward Culver. At mile 1, turn right (west) onto Belmont Drive. This road continues west for 8 mi to Round Butte Dam. At mile 3, Belmont Drive winds across Dry Canyon. The flows that form the rim of Dry Canyon are Agency Plains diktytaxitic basalts of the Deschutes Formation. They originated at Tetherow Butte, some 20 mi to the south, about million years ago. Trough-banded volcaniclastic sandstones of the Deschutes Formation representing channel fills are visible in the roadcut below the rim on the small canyon's west side. As you continue to climb, you are venturing onto the apron of basalts and cinders produced by Round Butte, the youngest of the Deschutes Formation eruptive centers.

STOP 1. Mile 3.8. Round Butte basalt and scenic views.

A low roadcut on the left (south) side of the road exposes the porphyritic basalts of Round Butte. These rocks have been dated at 3.9 million years (m.y.) (Smith, 1986a). Note the dark color and relatively smooth feel of these rocks. Their textures and compositions distinguish them from the more voluminous, vesicle-rich diktytaxitic flows that emanated from the Cascades.

The view from this location, as well as from the remainder of Belmont Drive, is inspiring. To the north, the Deschutes River canyon holds Lake Simtustus. Columbia River basalts, overlain by the sedimentary rocks of the Simtustus Formation, are visible in the lower canyon walls. The Deschutes Basin sweeps westward to Green Ridge, with the deep canyon of the Metolius River incised through it. The peaks of the High Cascades rise beyond Green Ridge. Mount Hood, Olallie Butte, Mount Jefferson, and Three Fingered Jack are visible from the north shoulder of Round Butte.

Continue west along Belmont Drive. At mile 6, turn left (south) onto Mountain View Drive. At the junction with Round Butte Drive, turn right (west) toward Cove Palisade State Park.

Mile 9.5: Park entrance.

STOP 2. Mile 10. View of Cove Palisades State Park.

Stop at the first parking area on the right past the park entrance. Peer carefully over the low wall at the edge of the parking lot. About 650 ft below, at the bottom of a sheer cliff of Deschutes

History and facilities of Cove Palisades State Park

(revised slightly from Peterson and Groh, 1970)

The Madras area of Jefferson County was initially settled about a century ago, and favorite fishing locations and places for relaxation were soon discovered in the deep canyons to the west. One of these places was on the banks of the Crooked River about 2 mi above its junction with the Deschutes River. This secluded spot, sheltered by canyon walls, came to be known as "The Cove."

Public and private development through the years improved the accessibility of The Cove, first with roads from Madras and later with bridges across the Crooked and Deschutes Rivers and a road connecting Grandview and Sisters to the west. A small hydroelectric plant was built at The Cove in 1912 and was enlarged in 1923 to provide power for the communities of Madras, Prineville, and Redmond. Even a peach orchard was established at The Cove, because the climate was quite mild at the bottom of the canyon.

In the late 1930's and early 1940's, the Oregon Highway Commission, which had recognized the recreational potential of the area, acquired through purchase and lease agreement from public and private holders some 7,000 acres of this canyon region. After World War II, trails and camping facilities were built, and the area was officially named "Cove Palisades State Park."

All of this began to change, though, for in 1960, the construction of Round Butte Dam began on the Deschutes River, just below the mouth of the Metolius River. This rock-fill dam has raised the water level nearly 400 ft above the bottom of the canyon. The old Cove Palisades State Park and the adjacent hydroelectric plant are now under 200 ft of water.

Through agreement with the State Parks and Recreation Division, Portland General Electric Company, owner of the dam, provided for a move of park facilities to a location about a mile to the southwest on the Deschutes River side of "The Peninsula." After the dam was completed. the reservoir created a three-armed body of water that is named Lake Billy Chinook for the Warm Springs Indian guide who accompanied Captain John C. Fremont in his early-day exploration of Oregon. The maps in Figures 1 and 2 show the extent of Lake Billy Chinook.

The present facilities of Cove Palisades State Park include a main overnight camping area near "The Ship" and a smaller area at the top of Crooked River grade. There are 272 campsites available, 87 with full trailer hookup, 91 with electricity, and 94 improved tent sites. The park is open year-round, with campgrounds open from mid-April until the end of October. Day-use areas provide parking, boat launching, picnicking, and swimming areas. A marina concession, open from mid-April until mid-October, offers boat rental, a restaurant, and a store. Further information about the facilities and reservations for group camping at Cove Palisades State Park may be obtained from the park offices, phone (503) 546-3412.

Formation rocks, is the Crooked River Arm of Lake Billy Chinook. The lumpy mass to the south between the cliff bottom and the lake, the location of the Cove Palisades Marina, is a landslide, probably late Pleistocene in age, as are the small peninsulas that jut into the water upstream and hummocky east slope of "The Island"—the flat-topped ridge of Newberry intracanyon basalt that separates the two rivers.

Continue south on Mountain View Drive about 1.5 mi to the third viewpoint.

STOP 3. Mile 11 (approximately). View of the canyons of the Deschutes and Crooked Rivers.

This viewpoint is almost directly above the Cove Palisades marina and east of "The Island." Both landslides that were viewed obliquely from Stop 2 can be observed again here.

This stop affords an excellent perspective of the Newberry intracanyon flows in the Crooked River canyon directly to the south. You can also see the intracanyon flows backed up into the Deschutes River canyon by the ponding of basalt flows at Cove Palisades.

Across the Crooked River arm and slightly to the south, at the narrow point that joins "The Island" with "The Peninsula," stands a sculptured, banded erosional remnant of the Deschutes Formation known as "The Ship." It consists of dark sandstone beds and two light-colored ignimbrite layers and will be examined much closer at Stop 6.

The arid country across the lake to the west is known as the "Lower Desert." This country was homesteaded in the early 1900's during a decade of abnormally high annual rainfall. Several communities, including Grandview and Geneva, sprang up.

However, by 1920, the abundant grass and potential for agriculture that was nourished by the unusual 10 to 15 in. of annual rainfall had literally dried up. Ranches could not survive on the thin soils above Deschutes Formation flows and the still-younger basalts from Squaw Back Ridge. All that is left now of the small farms and communities is a well-manicured cemetery at Grandview and a few wooden skeletons of dreams.

Continue south on Mountain View Drive to the "T" junction with Cove Palisades Drive. At this junction (mile 12), turn right (west) on Cove Palisades Drive. Continue half a mile past the entrance to Cove Palisades State Park. Drive just past the first campground entrance (Loop E) and pull off into large turnout on the left.

Warning: The road through Cove Palisades State Park is narrow and heavily traveled by recreational vehicles and trailers, especially during summer months. Be alert for traffic at all times while examining roadcuts in Cove Palisades State Park. Be sure your vehicle is parked completely off the roadway at any time that you stop in this area.

STOP 4. Mile 14. Crooked River Arm grade.

It is recommended that you walk down this grade in order to leisurely examine the variety of Deschutes Formation rocks exposed here. Drivers may wish to wait at this turnout until the group has reassembled at the bottom of the grade, as there is no good parking area at the bottom of this hill.

This extensive roadcut exposes a sequence of alternating sandstones, conglomerates, lapillistones, and ignimbrites that are typical of the Deschutes Formation. Two volcanic flows are present. The rimrock at the top of the grade (at the park entrance sign) is the Agency Plains flow from Tetherow Butte, a basalt of the Deschutes Formation that originated approximately 20 mi to the south. Like the Round Butte basalt, this flow is not diktytaxitic, and is a different chemical type than the Cascade diktytaxitic basalts of the Deschutes Formation. (See text above for details.)

Below this rimrock basalt and separated from it by coarse sandstones and a thick, white tuffaceous bed is a basaltic andesite that displays excellent columnar jointing. This flow is a channel-filling unit of probably limited extent and unknown origin.

Sandstones are mostly volcaniclastic sheet-flow and hyperconcentrated debris-flow deposits. Conglomerates are of either river channel or hyperconcentrated debris flow origin. (See text of accompanying paper for fuller discussion of these units.)

Two ignimbrites are exposed in this section and are the same units present in "The Ship." The first is a fairly well-consolidated, light-pink unit containing both light (rhyolite) and dark (andesite?) pumice. It is well exposed in roadcuts about 75 vertical ft below the rim. The second is the Cove ignimbrite, a white to gray, dense unit that overlies a conglomerate and cross-bedded sandstones about halfway down the grade. This ignimbrite displays classical planer bedding (base-surge deposits) at its base, becomes less consolidated upward, and in places is eroded by the overlying channel-fill deposits.

Overall, the story told by this section of the Deschutes Formation is that of a broad plain, with a braided river system running northward across it, distributing the intense load of volcanic debris shed into the basin. Stream channels (seen in outcrop as concave-upward, bedded, and often gravel-filled exposures that usually cut downward into underlying beds) are common here. Old soil horizons (paleosols) can be identified by the presence of carbon-stained cavities that were once the roots of trees and grasses of a wetter climate.

Fossils are comparatively rare in the Deschutes Formation, perhaps because the depositional system was fairly energetic and washed most plant and animal remains away. Tattered plant leaves are the most abundant and include sycamore and ash (Ashwill, 1983). The presence of some diatom-rich sedimentary layers attests to scattered, shallow lakes. Fossil salmon occur in some channel deposits (Cavender and Miller, 1973).

If you look south, over the bank from the roadway about 100 yd past the turn-out, you can see an excellent exposure of the contact between the layer-cake Deschutes Formation and the younger intracanyon Newberry basalt.

From the base of the grade, continue south about three-quarters of a mile on Cove Palisades Road. Watch for the large turnout on the right (west) side of the road below the Newberry basalts.

STOP 5. Mile 16. Newberry intracanyon basalts; recent and old landslides.

This stop offers a good view of the intracanyon Newberry basalts. Note the complex patterns of jointing. The lower, straight columns, which are called the "colonnade," form by slow, steady cooling. The curved, irregular columns above them are called the "entablature." Their feathery patterns develop because the presence of water within the basalt flow(s) causes the lava to cool and solidify at irregular rates and in diverse directions. The Newberry basalts here are composed of multiple flows that formed one or two cooling units. Their exceptional thickness is the result of ponding behind a basalt dam downstream. As a result, basalt lava that flowed down the Crooked River drainage was backed up almost 4 mi into the Deschutes River canyon.

Two landslides are apparent across the lake from this viewpoint. The oldest, probably of Pleistocene age, forms a peninsula that juts into the lake. Its rock layers slant northward, toward the viewer. It may have occurred when the Crooked River, swelled by glacial meltwaters, undercut the Newberry basalt flow.

The second landslide occurred in the wet winter of 1988. It is visible above the roadway across the lake. Most of the mass that moved in this slide is talus and colluvium and was not attached to the underlying bed rock. Continue across bridge, up the grade, and past Group Camping Area to the left. Proceed around curve and pull into large turnout on left (south) side of the road.

Figure 29. Petroglyph on a boulder that was moved to the base of "The Ship" near the headquarters of Cove Palisades State Park.

STOP 6. Mile 19. "The Ship" and Indian petroglyph (Figure 29).

The high, ragged promontory above the parking area is known as "The Ship." The thick, light-colored layers in this exposure of the Deschutes Formation are ignimbrites. The lower unit is the best consolidated and most extensive and is named the Cove ignimbrite. Dark layers are sandstones and conglomerates. The columnar basalts to the north are the Newberry intracanyon flows of "The Island."

Between "The Ship" and "The Island" lies the hummocky terrain of a large landslide. This slide extends southward along the Deschutes Arm and creates almost 2 mi^2 of relatively flat areas on which campground, day-use, launch areas, and the park headquarters are developed. Like the old landslide noted at the previous stop, this is most likely Pleistocene in age. The landmass is stable now and is thus a safe place for development and camping.

Continue southwest, past campgrounds and launch areas, to the Deschutes Arm bridge. Cross the bridge and park in the turnout to the right.

STOP 7. Mile 20. The Deschutes Arm grade.

Again, it is recommended that you take the time to walk up this grade and examine the details of the Deschutes Formation. (Less hardy souls may wish to drive up and walk down.)

The Deschutes Arm grade exhibits a number of features that contrast with those apparent on the Crooked River Arm grade. The rimrock here is diktytaxitic basalt of the Canadian Bench flow of the Lower Desert basalt—flows of the Deschutes Formation that originated in the Cascades. Several coarse debris flows are present near the top of the grade, and, in general, the sediment is slightly coarser. The Cove ignimbrite, as well as a pinkish-gray ash flow slightly higher in the section, can be examined along this grade.

At the switchback, a close view of the contact between intracanyon flows and the underlying Deschutes Formation reveals a reddish baked zone.

Perhaps one of the most interesting features of this grade is the diktytaxitic basalt exposed in a roadcut about 200 yd below the switchback curve. There are three thin flows of this basalt. All display an excellent set of pipe vesicles.

These unusual, and here, classical, features are slender, cylindrical cavities extending upward from the base of a lava flow. They commonly have a top that is bent at a right angle, indicating the direction that the lava was moving at the time it cooled. They are formed by water vapor that is trapped beneath a lava flow and streams upward into the moving lava as steam. The inside of most pipe vesicles is glassy.

From the top of this grade, the adventurous may wish to take Forest Service Road 64 to Forest Service Road 63, to the Gateway Cemetery, a distance of about 4 mi. Those of a less historical bent may end the Cove Palisades Field Trip here.

GLOSSARY

Anorthosite: A plutonic igneous rock composed almost entirely of plagioclase feldspar. These rocks are rare now but formed significant portions of the earth's early continents and island arcs from 2.4 to 1.2 billion years ago.

Clast-supported: A sedimentary rock fabric in which larger clasts form the supporting framework, and finer grained particles simply fill the limited amount of space between large cobbles or pebbles.

Dacite: A volcanic rock intermediate in composition between rhyolite and andesite.

Diktytaxitic: A texture in volcanic rocks characterized by small, irregular vesicles (holes), bounded and often lined with small crystals of plagioclase feldspar. Most commonly found in basalts, a diktytaxitic texture imparts a rough, sharp feeling to a fresh surface.

Graded bedding: A type of sedimentary bedding showing gradual change in particle size, normally from coarse at the bottom to fine at the top. In reverse bedding, the coarse particles are at the top.

Ignimbrite: A volcanic (volcaniclastic) rock formed by deposition of a hot cloud of ash and gas ejected laterally from a volcano.

Matrix-supported: A sedimentary rock in which larger clasts rest passively in a matrix of finer grained material.

Normally graded: See "Graded bedding."

Peperite: Explosive intrusions of magma into wet sediment, producing a mixed and chaotic rock containing angular fragments of volcanic rock, glass, clays, and sediment.

Phenocryst: A crystal that is visible to the naked, unaided eye, usually within a fine-grained, volcanic rock.

Porphyritic: An igneous rock texture, usually in volcanic rocks, wherein two different-sized populations of crystals occur in the rock, or where larger crystals are set in a fine-grained groundmass.

Pyroclastic rocks: Fragments produced by direct and commonly explosive volcanic action.

Reversely graded: See "Graded bedding."

Rhyodacite: A volcanic rock intermediate in composition between rhyolite and dacite.

Stratovolcano: A volcano composed of alternating lava and ash or cinders and other pyroclastic material. Most large volcanic cones, including Mount Hood and Mount Jefferson, are stratovolcanoes.

Tholeiite: A high-silica basalt, usually containing abundant pyroxene.

Volcanic arc: An arcuate chain of volcanoes above a subduction zone.

Volcaniclastic rocks: Fragmental rocks composed predominantly of reworked or eroded volcanic material.

Xenolith: An inclusion of an exotic or foreign rock in an igneous rock, rather like a raisin in a pudding.

(***References***, continued from page 10)

Smith, G.A., 1986a, Stratigraphy, sedimentology, and petrology of Neogene rocks of the Deschutes Basin, central Oregon: A record of continental margin volcanism: Corvallis, Oreg., Oregon State University doctoral dissertation, 467 p.

———1986b, Coarse-grained nonmarine volcaniclastic sediment: Terminology and depositional processes: Geological Society of America Bulletin, v. 97, p. 1-10.

———1986c, The Simtustus Formation: Paleographic and stratigraphic significance of a newly defined Miocene unit in the Deschutes basin, central Oregon: Oregon Geology, v. 48, no. 6, p. 63-72.

———1987a, Geologic map of the Seekseequa Junction and a portion of the Metolius Bench quadrangles, Jefferson County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-44.

———1987b, Geologic map of the Madras West and Madras East quadrangles, Jefferson County, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-45.

Smith, G.A., Taylor, E.M., Enlows, H.C., and Thormahlen, D., 1984, Three newly recognized occurrences of Rattlesnake ignimbrite in central Oregon (abs.): Oregon Academy of Science Proceedings, v. 20, p. 59.

Sparks, R.S.J., Self, S., and Walker, G.P.L., 1973, Products of ignimbrite eruptions: Geology, v. 1, p. 115-118.

Taylor, E.M., and Smith, G.A., 1987, Record of early High Cascade volcanism at Cove Palisades, Oregon: Deschutes Formation volcanic and sedimentary rocks, *in* Hill, M., ed., Cordilleran Section of the Geological Society of America: Decade of North American Geology, Centennial Field Guide, v. 1, p. 313-315.

Thormahlen, D., 1985, Geology of the northwest quarter of the Prineville quadrangle: Corvallis, Oreg., Oregon State University master's thesis, 106 p.

Uppuluri, V.R., 1974, Prineville chemical type: A new basalt of the Columbia River Group: Geological Society of America Bulletin, v. 85, p. 1315-1318.

Vance, J.A., 1988, New fission-track and K/Ar ages from the Clarno Formation, Challis age volcanic rocks in north-central Oregon: Geological Society of America Abstracts with Program, v. 20, p. 473.

Yogodzinski, G.M., 1986 (compl. 1985), The Deschutes Formation—High Cascade transition in the Whitewater River area, Jefferson County, Oregon: Corvallis, Oreg., Oregon State University master's thesis, 165 p. □

Fear in a handful of numbers*

by Dennis Overbye. Copyright 1989 The Time Inc. Magazine Company. Reprinted by permission.

Everybody talks about the weather, goes the saying (often wrongly attributed to Mark Twain), *but nobody does anything about it*. The word from scientists is that whoever said this was wrong. All of us, as we go about the mundane business of existence, are helping change the weather and every other aspect of life on this fair planet: Los Angelenos whipping their sunny basin into a brown blur on the way to work every morning; South Americans burning and cutting their way through the rain forest in search of a better life; a billion Chinese, their smokestacks belching black coal smoke, marching toward the 21st century and a rendezvous with modernization.

On the flanks of Mauna Loa in Hawaii, an instrument that records the concentration of carbon dioxide dumped into the atmosphere as a result of all this activity traces a wobbly rising line that gets steeper and steeper with time. Sometime in the next 50 years, say climatologists, all that carbon dioxide, trapping the sun's heat like a greenhouse, could begin to smother the planet, raising temperatures, turning farmland to desert, swelling oceans anywhere from four feet to 20 feet. Goodbye Venice, goodbye Bangladesh. Goodbye to millions of species of animals, insects, and plants that haven't already succumbed to acid rain, ultraviolet radiation leaking through the damaged ozone layer, spreading toxic wastes, or bulldozers.

A species that can change its planet's chemistry just by day-to-day coming and going has, I suppose, achieved a kind of coming-of-age. We could celebrate or tremble. What do we do when it is not war that is killing us but progress? When it is not the actions of a deranged dictator threatening the world but the ordinary business of ordinary people? When there are no bombs dropping, nobody screaming, nothing to fear but a line on a graph or a handful of numbers on a computer printout? Dare we change the world on the basis of a wobbly line on a graph? We can change the world, and those numbers, slowly, painfully—we can ration, recycle, carpool, tax, and use the World Bank to bend underdeveloped nations to our will. But the problem is neither the world nor those numbers. The problem is ourselves.

In our relations with nature, we've been playing a deadly game of cowboys and Indians. We all started as Indians. Many primitive cultures—and the indigenous peoples still clinging today to their pockets of underdevelopment—regarded the earth and all its creatures as alive. Nature was a whistling wind tunnel of spirits. With the rise of a scientific, clockwork cosmos and of missionary Christianity, with its message of man's dominion and relentless animus against paganism, nature was metaphorically transformed. It became dead meat.

The West was won, Los Angeles and the 20th century were built, by the cowboy mind. To the cowboy, nature was a vast wilderness waiting to be tamed. The land was a stage, a backdrop against which he could pursue his individual destiny. The story of the world was the story of a man, usually a white man, and its features took their meaning from their relationship to him. A mountain was a place to test one's manhood; an Asian jungle with its rich life and cultures was merely a setting for an ideological battle. The natives are there to be "liberated." By these standards even Communists are cowboys.

The cowboys won—everywhere nature is being tamed—but victory over nature is a kind of suicide. The rules change when there is only one political party allowed in a country or there is only one company selling oil or shoes. So too when a species becomes numerous and powerful enough to gain the illusion of mastery. What we have now is a sort of biological equivalent to a black hole, wherein a star becomes so massive and dense that it bends space and time totally around itself and then pays the ultimate price of domination by disappearing.

Modern science, a cowboy achievement, paradoxically favors the Indian view of life. Nature is alive. The barest Antarctic rock is crawling with microbes. Viruses float on the dust. Bacteria help digest our food for us. According to modern evolutionary biology, our very cells are cities of formerly independent organisms. On the molecular level, the distinction between self and nonself disappears in a blur of semipermeable membranes. Nature goes on within and without us. It wafts through us like a breeze through a screened porch. On the biological level, the world is a seamless continuum of energy and information passing back and forth, a vast complicated network of exchange. Speech, food, posture, infection, respiration, scent are but a few pathways of communication. Most of those circuits are still a mystery, a labyrinth we have barely begun to acknowledge or explore.

The great anthropologist and philosopher Gregory Bateson pointed out 20 years ago that this myriad of feedback circuits resemble the mathematical models of thinking being developed for the new science of artificial intelligence. A forest or a coral reef or a whole planet, then, with its checks and balances and feedback loops and delicate adjustments always striving for light and equilibrium, is like *a mind*. In this way of thinking, pollution is literal insanity (Bateson was also a psychologist). To dump toxic waste in a swamp, say, is like trying to repress a bad thought or like hitting your wife every night and assuming that because she doesn't fight back, you can abuse her with impunity—30 years later she sets your bed on fire.

Some of these circuits are long and slow, so that consequences may take years or generations to manifest themselves. That helps sustain the cowboy myth that nature is a neutral, unchanging backdrop. Moreover, evolution seems to have wired our brains to respond to rapid changes, the snap of a twig or a movement in the alley, and to ignore slow ones. When these consequences do start to show up, we don't notice them. Anyone who has ever been amazed by an old photograph of himself or herself can attest to the merciful ignorance of slow change, that is, aging—*Where did those clothes and that strange haircut come from? Was I really that skinny?*

We weren't born with the ability to taste carbon dioxide or see the ozone layer, but science and technology have evolved to fill the gap to help us measure what we cannot feel or taste or see. We have old numbers with which, like old photographs, we can gauge the ravages of time and our own folly. In that sense, the "technological fix" that is often wishfully fantasized—cold fusion, anyone?—has already appeared. The genius of technology has already saved us, as surely as the Ghost of Christmas Future saved Scrooge by rattling the miser's tight soul until it cracked. A satellite photograph is technology, and so are the differential equations spinning inside a Cray supercomputer. There is technology in the wobbly rising trace on a piece of graph paper. There is technology in a handful of numbers.

The trick is to become more like Indians without losing the best parts of cowboy culture—rationalism and the spirit of inquiry. We need more science now, not less. How can we stretch our nerves around those numbers and make them as real and as ominous

*This thought-provoking essay was originally published in the October 9, 1989, issue of *Time* magazine (page 119) and is reprinted here, with permission of the publishers, in the hope that it will be of interest to you, our readers. We hope to make other additions to *Oregon Geology* in future issues. Please let us have your ideas on changes you would like to see in the magazine. We welcome your ideas.

as our cholesterol readings? Repeat them each night on the evening news? We need feedback, as if we were the audience in a giant public radio fund-raising drive hitting the phones and making pledges. Like expert pilots navigating through a foggy night, we need the faith to fly the planet collectively by our instruments and not by the seat of our pants. In the West we need the faith and courage to admit the bitter truth, that our prosperity is based as much on cheap energy as on free markets. A long-postponed part of the payment for that energy and prosperity is coming due if we want to have any hope of dissuading the Chinese and the rest of the Third World from emulating us and swaddling the planet with fumes and wastes.

What if the spirit doesn't hit? We can't afford to wait if we want to survive. While we are waiting for this sea change of attitude, we could pretend—a notion that sounds more whimsical than it is. Scientists have found that certain actions have a feedback effect on the actor. Smilers actually feel happier; debaters become enamored of their own arguments; a good salesman sells himself first. You become what you pretend to be. We can pretend to be unselfish and connected to the earth. We can pretend that 30-ft-long, black-tinted-glass, air-conditioned limos are unfashionable because we know that real men don't need air conditioning. We can pretend that we believe it is wrong to loot the earth for the benefit of a single generation of a single species. We can pretend to care about our children's world.

The air has been poisoned before, 3 billion years ago, when the blue-green algae began manufacturing oxygen. That was the first ecological crisis. Life survived then. Life will not vanish now, but this may be the last chance for humans to go along gracefully. □

Agency welcomes Tom Wiley and Frank Hladky to Grants Pass Field Office

Thomas J. Wiley, formerly of the U.S. Geological Survey (USGS), and Frank R. Hladky, formerly of private industry, have joined the Oregon Department of Geology and Mineral Industries (DOGAMI) as professional staff for the Grants Pass Field Office located in southwestern Oregon.

Tom Wiley finished a Bachelor of Science degree in 1979 at Humboldt State University in northern California. He received his Master's degree in geology from Stanford University in 1983. As a USGS geologist, his principal duties included conducting geologic mapping and other field studies focused on the understanding of sedimentary basins and basement terranes in western North America. This background is particularly appropriate for the Grants Pass Field Office geologist. Tom's work included studies of the geology in and around western Oregon as part of regional syntheses of tectonics and petroleum potential. He compiled the geology of the Pacific Ocean floor west of Oregon for a new geologic map published by the Geological Society of America and worked in Tertiary basins of the Franciscan terrane of California. In addition, he has participated in field studies in Alaska, the People's Republic of China, and Tibet.

Tom recently assisted in organizing and coordinating the Third Circumpacific Tectonostratigraphic Terrane Conference held in 1985 in Sydney, Australia, and was North American Coordinator for the Fourth Circumpacific Tectonostratigraphic Terrane Conference held in 1988 in Nanjing, People's Republic of China. Tom Wiley has numerous publications to his credit.

Thomas J. Wiley.

Frank R. Hladky.

Also joining DOGAMI as a project geologist is Frank Hladky, a recent employee of Newmont Exploration, Ltd. Frank's experience in recent years included that of research associate at Idaho State University, during which time he performed a geologic assessment of tribal lands in southern Idaho that are administered by the U.S. Bureau of Indian Affairs. The project resulted in several significant maps and other reports, either published by or in press at the USGS.

Frank received his Bachelor of Science degree in geology from the University of Oregon in 1982 and his Master of Science degree in geology from Idaho State University in 1986. His most recent exploration for Newmont included regional and strategic analyses of the Carlin Trend for the purpose of gold exploration in the western United States. His primary areas of interest include structure, deformational events, stratigraphy, and timing and mechanisms of ore emplacement. Frank also has numerous geologic publications to his credit.

DOGAMI is pleased to continue its many years of effort in the Grants Pass area on behalf of the citizens and interests of Oregon and is especially pleased to add to its staff two highly qualified professional geologists in Tom Wiley and Frank Hladky. □

McMurray rejoins DOGAMI

Gregory McMurray rejoined the staff of the Oregon Department of Geology and Mineral Industries (DOGAMI) as Marine Minerals Program Coordinator on November 13, 1989.

McMurray had served in this position between September 1984 and January 1989 as coordinator for the State/Federal Gorda Ridge Technical Task Force and will now continue in a similar function for the State/Federal Oregon Placer Minerals Task Force. His duties will concentrate on providing management and technical support for non-Department scientific working groups that study the various aspects of offshore mineral exploration and development.

A biological oceanographer, McMurray received his Bachelor's degree in zoology from Ohio University, his Master's degree in biology (limnology) from the University of Akron, and his Doctor's degree in oceanography from Oregon State University. As a senior oceanographer at VTN Oregon, Inc., he was project manager and principal investigator for physical, chemical, and biological oceanographic studies of the Pacific Coast estuaries and fjords. He has also served with the U.S. Geological Survey, studying the phytoplankton ecology of San Francisco Bay and the lower Sacramento River. During 1989, following his first term with DOGAMI, McMurray was Deputy Director for the National Coastal Resources Institute at Newport, Oregon, and, later, a consultant to Exxon for environmental studies of the Prince William Sound oil spill in Alaska.

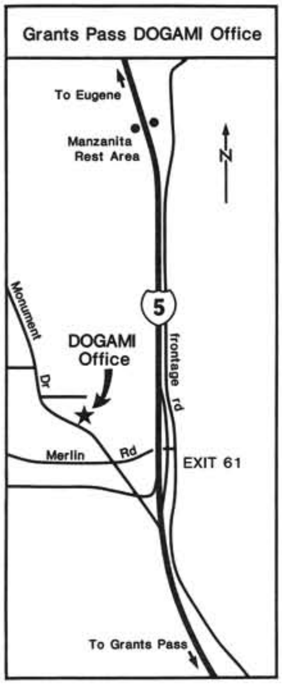
Gregory McMurray.

McMurray is author and coauthor of numerous papers and reports based on his oceanographic studies in Alaska, California, and Oregon. He is the editor of the recent Springer-Verlag publication containing results of studies of the Gorda Ridge Task Force. (See page 21 of this issue.) □

DOGAMI reopens Grants Pass Field Office in new location

The Oregon Department of Geology and Mineral Industries (DOGAMI) is pleased to announce the reopening of its field office in Grants Pass with responsibilities for southwestern Oregon, an area that encompasses not only the Klamath Mountains but also part of the Coast Range and part of the Cascade Range and that extends into the Basin and Range province. Closure of the office appeared imminent, owing to successive budget cuts, but public and legislative interest enabled the Agency to reopen the office at its new facilities in joint quarters with the State Forestry Department at 5375 Monument Drive, Grants Pass.

Major missions of the Agency include the ongoing collection of meaningful geologic data for the public good, education of the public and government in geologic matters, regulation of such geologic activities as oil and gas and geothermal exploration and production, mineral exploration and mining, and, finally, participation in the development of public policy on resource-oriented issues.



Sketch map showing new location of DOGAMI Grants Pass Field Office.

Within this context, the activities of the Grants Pass Field Office will be extremely important in southwestern Oregon, an area of intense geologic interest and policy issues. Primary work load for the office will be oriented toward geologic data collection and mapping plus information dissemination to a broad audience, including private industry, government agencies, and the public in general.

The new location of the DOGAMI Grants Pass Field Office is at the same address as the State Forestry Department: 5375 Monument Drive, Grants Pass, OR 97526. The location is approximately 3 mi north of Grants Pass and just west of Interstate Highway I-5 (see sketch map).

After the retirement of former Grants Pass Field Office geologists Norm Peterson, five years ago, and Len Ramp, approximately a year ago, the office has now been restaffed with new geologists identified in a nationwide recruiting effort that took eight months to complete. Running the office will be Tom Wiley, formerly of the U.S. Geological Survey. Working in close harmony with him will be Frank Hladky, who comes to the Agency from private enterprise.

During the winter months, the Agency will be addressing policy issues and broad geologic riddles in southwestern Oregon in a systematic approach to identifying at least one broad, multi-year project into which to place its efforts. Emphasis will be on identifying a project of value to the people of southwestern Oregon, with promise of attracting supplemental efforts from Federal agencies, possibly including the U.S. Geological Survey, and private industry. It is the Agency's belief that, in terms of project design, a partnership effort in a broad area over a reasonable period of time yields the greatest long-term payoffs for Oregon. We welcome Tom Wiley and Frank Hladkey into the Agency and look forward to many years of productive work with them. □

BOOK REVIEW

by Ralph S. Mason, former State Geologist of Oregon

William A. Rockie, Seventy Years a Geographer in the West. Written by W.A. Rockie, compiled and updated by John D. Rockie, edited by Larry W. Price. Published 1989 by Department of Geography, Portland State University, P.O. Box 751, Portland, Oregon 97207. 70 p., $11.95.

All autobiographies should be viewed with a certain amount of circumspection by a reviewer. Fact and fiction, unvarnished truths, adventures and misadventures lie like mine fields along their paths. Here is an account, put together by the author over a period of many years but never completed before his death. It was eventually augmented with the help of some of William Rockie's professional friends at the Department of Geography at Portland State University, and the combined material was then compiled by his son John. To complicate matters even more, the reviewer knew the author for nearly forty years, both professionally and as a good friend and neighbor.

Unavoidably, there are gaps in the telling, but the message comes through loud and clear. Here was a man who participated in the earliest beginnings of the soil conservation movement and then pushed and prodded the fledgling movement for the next half century. If nothing else, this account provides an almost complete history of the growing awareness of the need for soil conservation in this country—and odd places scattered around the world as well.

If anything, Rockie understates many of his multitudinous activities and observations. His transect of the Sahara from Algiers to Lagos, Nigeria, is a case in point. One interesting anecdote he related upon his return from this project is not in his book: During a lunch stop in the desert, Rockie removed a square foot of wind-polished pebbles that formed the lag blanket. Steadily, the wind blew away the unprotected sand, and a miniature "blowout" formed even as he watched. On another occasion he told of riding a small landslide in the Matanuska Valley, Alaska, down a slope of only two degrees—revamping for all time old ideas about the "angle of repose." One wonders how many other similar observations Rockie might have included if he could have completed his book himself. A latter-day Boswell could certainly have embellished the text with a wealth of informal material.

Interestingly, mention is made that, at the oasis of Tamanrasset in Algeria, Rockie inventoried a small portion of the irrigated area and counted 26 different species among a total of 2,294 trees—in an area previously reported to have but one "spiky gnarled willow." Fact is often more interesting than fiction! ☐

NEF publishes poster on mining

The National Energy Foundation (NEF) has announced the publication of an educational poster entitled "From Mountains to Metal. The Story of Rocks, Minerals, and the Mining Industry."

The colored poster is approximately 2 x 3 ft large and depicts in drawings explained by text eight steps from exploration for minerals to reclamation of mined sites. The back of the poster is filled with large-print text, tables, and graphic illustrations presenting "Helpful Information to Teach about Rocks, Minerals, and the Mining Industry."

The poster is available from the National Energy Foundation, 5160 Wiley Post Way, Suite 200, Salt Lake City, Utah 84116, phone (801) 539-1406. The price of the poster is $2.50, and various discounts are offered for orders of 100 copies or more. For shipping and handling, a minimum of $3 or 10 percent of the order amount is charged.

—NEF news release

DOGAMI releases limestone report and Adrian quadrangle map

New report on limestone in Oregon

A comprehensive report on limestone in Oregon, its formation, industrial uses, and occurrences, has been released by the Oregon Department of Geology and Mineral Industries (DOGAMI). The report is intended to serve as a basis for further study and exploration and for the continued development of limestone as an industrial-mineral resource in Oregon's economy.

Limestone Deposits in Oregon, by DOGAMI geologist Howard C. Brooks and with an appendix by DOGAMI geochemist Gary L. Baxter, has been published as DOGAMI Special Paper 19.

The report consists of a 72-page text with numerous illustrations, especially location maps and analytical tables, and two separate plates. Plate 1 presents locations and analytical data for nearly 300 samples collected and analyzed for this report. Plate 2 contains a map of limestone deposits and areas in Oregon keyed to the discussion in the text.

Oregon's approximately 40-million-ton output of crushed and ground limestone has been used mainly in the production of about 18.5 million tons of cement. Other major uses of Oregon's limestone have been the production of industrial and agricultural lime; fillers, extenders, and mineral pigments for such products as plastics, paint, rubber, floor coverings, adhesives, and paper; surface coatings for paper manufacture; and refining agents for sugar production.

The limestone has come mainly from metamorphosed high-calcium deposits of Palozoic and Mesozoic age in the Blue Mountains and Klamath Mountains and from low-grade deposits of Tertiary age in the Coast Range. Eastern Oregon has local occurrences of lacustrine carbonate beds and small travertine deposits.

New geologic quadrangle map for Adrian area

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released a new geologic map that describes in detail the geology and mineral potential of a portion of the Owyhee region in eastern Oregon near the city of Adrian. Geothermal energy is the only minral resource known to exist, but potential for natural gas and, to a lesser extent, gold or uranium has also been identified.

Geology and Mineral Resources Map of the Adrian Quadrangle, Malheur County, Oregon, and Canyon and Owyhee Counties, Idaho, by DOGAMI geologist Mark L. Ferns, has been released in DOGAMI's Geological Map Series as map GMS-56. The publication, resulting from an ongoing study of southeastern Oregon areas with a potential for mineral resources, was prepared in cooperation with the U.S. Geological Survey (USGS) and the Idaho Geological Survey and partially funded by the COGEOMAP program of the USGS.

The Adrian 7½' Quadrangle covers approximately 48 square miles along the Owyhee River around the river's Big Bend area south of Adrian. The two-color map of the quadrangle (scale 1:24,000) identifies eight rock units, the oldest of which are approximately 15 million years old. Geologic structure is described both on the map and in the accompanying geologic cross section. The approximately 27- by 38-inch map sheet also includes a discussion of the quadrangle's mineral resource potential and a table showing trace-element analyses of rock samples.

The two new releases are now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201-5528. The price for Special Paper 19 is $8, for map GMS-56 $4. Orders may be charged to credit cards by mail, FAX, or phone. FAX number is (503) 229-5639. Orders under $50 require prepayment except for credit-card orders. ☐

MINERAL EXPLORATION ACTIVITY

Major metal-exploration activity

Date	Project name, company	Project location	Metal	Status
April 1983	Susanville Kappes Cassiday and Associates	Tps. 9, 10 S. Rs. 32, 33 E. Grant County	Gold	Expl
May 1988	Quartz Mountain Wavecrest Resources Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
June 1988	Noonday Ridge Bond Gold	T. 22 S. Rs. 1, 2 E. Lane County	Gold, silver	Expl
September 1988	Angel Camp Wavecrest Resources, Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
September 1988	Glass Butte Galactic Services Inc.	Tps. 23, 24 S. R. 23 E. Lake County	Gold	Expl
September 1988	Grassy Mountain Atlas Precious Metals, Inc.	T. 22 S. R. 44 E. Malheur County	Gold	Expl, com
September 1988	Kerby Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	Expl, com
September 1988	QM Chevron Resources, Co.	T. 25 S. R. 43 E. Malheur County	Gold	Expl
October 1988	Bear Creek Freeport McMoRan Gold Co.	Tps. 18, 19 S. R. 18 E. Crook County	Gold	Expl
December 1988	Harper Basin American Copper and Nickel Co.	T. 21 S. R. 42 E. Malheur County	Gold	Expl
January 1989	Silver Peak Formosa Exploration, Inc.	T. 31 S. R. 6 W. Douglas County	Copper, zinc	App, com
May 1989	Hope Butte Chevron Resources, Co.	T. 17 S. R. 43 E. Malheur County	Gold	Expl, com
September 1989	East Ridge Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	App

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

Exploration rule making

The Technical Advisory Committee organized to make recommendations on exploration permit rule making relative to House Bill 2088 has met twice and will meet next in Salem on January 10, 1990. It is expected that three public hearings and a two-week comment period will be used to receive public comment on draft rules. The hearings will likely be scheduled for March or April. Anyone wishing to be on the draft rule mailing list should contact Doris Brown at the Oregon Department of Geology and Mineral Industries (DOGAMI) Mined Land Reclamation, 1534 Queen Avenue SE, Albany, OR 97321, phone (503) 967-2039.

Bond ceiling rule making

The Technical Advisory Committee organized to make recommendations on rule making relative to bond ceilings (Senate Bill 354) has met twice and will meet again January 9, 1990. The track for rule making is similar to that for the above-mentioned exploration rule making process, and again three public hearings and a two-week comment period will be used to receive public input. Anyone wishing to receive draft rules should contact Doris Brown at the address or telephone number above.

Status changes

Atlas Precious Metals has submitted a plan of operations to the U.S. Bureau of Land Management (BLM). An Environmental Impact Statement for the site will be required by BLM. The Atlas project coordinating committee met on December 19, 1989, to discuss NEPA compliance and agency permitting schedules.

Formosa Exploration, Inc., has submitted its baseline studies and operating plan for the Silver Peak Mine to DOGAMI and the Department of Environmental Quality.

All readers who have questions or comments should contact Gary Lynch or Allen Throop at the MLR office in Albany, phone (503) 967-2039. □

DOGAMI receives funding for earthquake hazard mitigation

On November 15, 1989, the Oregon Department of Geology and Mineral Industries (DOGAMI) requested $489,285 from the State Emergency Board to support earthquake hazard mitigation. On December 15, 1989, the Emergency Board allocated $230,000 of State General Fund to DOGAMI for earthquake hazard mitigation. The allocation includes funds for an earthquake engineer and for subcontracted studies and support for a seismic network.

Recent findings by researchers working on Oregon and Washington coastal marshes indicate that the Northwest may be vulnerable to damage from great subduction-zone earthquakes. The action by the Emergency Board is in response to this newly recognized threat.

DOGAMI has assembled an advisory panel to assist in deciding on priorities for the State program and provide ongoing advice regarding information needs. □

Gorda Ridge subject of new book

A book entitled *Gorda Ridge: A Seafloor Spreading Center in the United States' Exclusive Economic Zone* has been released by Springer-Verlag New York, Inc. It contains the proceedings of the Gorda Ridge Symposium, conducted in Portland, Oregon, during May 1987 under the sponsorship of the joint state/federal Gorda Ridge Technical Task Force and was edited by Greg McMurray of the staff of the Oregon Department of Geology and Mineral Industries. The Gorda Ridge Task Force was active in directing and coordinating research on Gorda Ridge from 1984 through 1988.

The new volume presents a summary of recent advances in seafloor research related to mineral exploration on the ridge, which is the only seafloor-spreading center within the 200-nautical-mile-wide Exclusive Economic Zone of the United States. The book includes sections on the results of Gorda Ridge mineral exploration, on the newest technologies for mineral exploration and sampling on the seafloor, on the evolving field of hydrothermal-vent biology and ecology, and on the exploration of sediment-hosted sulfide deposits discovered in the southern segment of Gorda Ridge. The book is of interest to researchers in marine geology and biology as well as to those involved in ocean-policy development and environmental issues.

Cost of the new book is $89. More information may be obtained from the publisher by writing Springer-Verlag New York, Inc., P.O. Box 2485, Seacaucus, NJ 07096-2491. □

ABSTRACTS

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

STRATIGRAPHY AND SEDIMENTARY PETROLOGY OF THE MASCALL FORMATION, EASTERN OREGON, by John L. Kuiper (M.S., Oregon State University, 1988), 153 p.

The type section of the Mascall Formation, which is located in the John Day Valley, is interpreted to represent a sequence of paleosols. These fossil soils were formed on a flood plain during the middle Miocene. The measured thickness of this section is 1,340 ft, and although the top of the section is truncated by an erosion surface, the original thickness was probably not much more than 2,000 ft. Sediment accumulation rates were high in the vicinity of the type section, with deposits being predominantly of the overbank type. Minimum sediment accumulation time at the type section is thought to have been several hundred thousand years.

A concretionary horizon that occurs within the type section is determined to represent a significant temporal hiatus. Because of the absence of caliche in this layer and elsewhere in the type section and because of the occurrence of moisture-loving plants, a wet, temperate climate during the middle Miocene (Barstovian) is envisioned for the type section.

The flood-plain sediments of the type section are predominantly composed of ash that was produced by nearby silicic volcanism. This ash was mostly washed in from the surrounding highlands, but on occasion the flood plain was blanketed by air-fall debris. Scanning electron microscopy demonstrates that this ash is of the type erupted by Plinian- and Peléan-type volcanoes. The ash has been mostly altered to clay minerals, and SEM, TEM, and XRD analyses show these clays to consist principally of smectite (Ca, Mg) with lesser amounts of kaolin and tubular halloysite.

Deposits west of Picture Gorge are predominantly of flood-plain origin; however, a limited lacustrine sequence also occurs. East of the type section, the flood-plain deposits tend to become coarser and reflect main-channel deposition.

Farther to the east, near the mouth of Fields Creek, a 300-ft-thick lacustrine sequence occurs, representing a shallow eutrophic lake that was at least 3.5 mi in east-west dimension.

Mascall deposits of the Paulina Basin also were formed in a flood-plain environment. The area was characterized by slow sediment accumulation rates, and river meandering resulted in deposition of large tabular sandstone bodies. Meander-loop cutoff probably occurred often, and as a result the flood plain was probably dotted with oxbow lakes. Volcanoes were active nearby and on occasion covered the flood plain with pyroclastic debris.

The Mascall Formation is believed to have been deposited only in the structural and topographic lows of the time. Present occurrences of Mascall rocks in the John Day Valley, Paulina Basin, and Fox Basin and Miocene rocks in the Bear Valley and Unity Basin that may or may not be Mascall are not the remnants of a huge alluvial fan. Rather, all of these structural lows were filled with sediment and pyroclastic material from their respective adjacent highlands.

Pumices ranging from white to black in color, representing a zoned eruption, were collected from Mascall deposits in the John Day Valley. Chemical analysis of these pumices precludes magma mixing as a means of producing the zoned eruption. It is not known whether crystal fractionation or assimilation of wall-rock material represents the mechanism involved. High K_2O values in the Mascall pumice show the magma had a continental source.

THE STRATIGRAPHY AND DEPOSITIONAL SETTING OF THE SPENCER FORMATION, WEST-CENTRAL WILLAMETTE VALLEY, OREGON; A SURFACE-SUBSURFACE ANALYSIS, by Linda J. Baker (M.S., Oregon State University, 1988), 171 p.

The upper Eocene Spencer Formation crops out in the low hills on the western edge of the central Willamette Valley, Oregon. Surface exposures in eastern Benton and southeastern Polk Counties and oil and gas well records and cuttings in Polk, Marion, and Linn Counties were studied to determine Spencer stratigraphy, regional lithologic variations, and depositional environment. Methods used include study of outcrops, petrography, texture, and well cuttings, as well as correlation of well logs and microfossil data. The distribution of the underlying lower upper Eocene Yamhill Formation is also briefly considered.

The Yamhill Formation consists of the Miller sandstone member enclosed between mudstones. The lower and middle Yamhill units record shoaling from bathyal to marginal marine depths, and they are overlain by bathyal upper Yamhill mudstones. The Miller sandstone is lens shaped, trends parallel to the Corvallis fault, and reaches a maximum thickness of approximately 2,000 ft on the east side of the fault. The Miller sandstone grades westward into bathyal mudstones and eastward into volcanic tuffs and flows. Thinning of the Miller sandstone and upper Yamhill mudstone along the Corvallis fault suggests movement during early late Eocene. The absence of Yamhill strata along the outcrop belt to the southwest may be related to this tectonic activity. Alternatively, Yamhill strata may have been misidentified as Tyee Formation or Spencer Formation.

The Spencer Formation was deposited in a tectonically active forearc basin during a transgression that was interrupted by several short-term regressional/progradational events. The Spencer is stratigraphically divided (informally) into a lower sandstone-rich member and an upper mudstone member; it is also divided geographically (informally) into northwestern, east-central, and southern provinces. The lower member is 700 ft thick in the northwestern and southern areas and thickens to 1,400 ft in the east-central area. As compared to the north and south areas, sandstones in the east-central area are coarser (fine to medium versus very fine to fine), the sandstone-to-siltstone ratio is higher, and volcanic interbeds are more common. Deposition is thought to have been at inner-shelf and shoreface depths, grading eastward into nonmarine. In the northwestern area, abundant hummocky cross-bedding of arkosic to arkosic-lithic lower Spencer sandstones suggests deposition on a storm-wave-dominated shelf. Periods of shoaling to shoreface depths are indicated. In the south, sandstones are markedly more volcanic-rich (dominantly arkosic litharenites), contain more fossils, and are more highly bioturbated. Shelf-storm deposits in the south are normally graded with a basal lag of coarse volcanic grains and fossils. Besides a more proximal volcanic source, a shoal/barrier within the southern part of the basin may have caused the different sediment character. Deposition was probably at middle- to inner-shelf depths at the outcrop belt. It may have deepened slightly eastward before shoaling to nonmarine in the easternmost part of the study area. Volcanism was active nearby on the eastern and southeastern margins of the basin. Small volcanic centers within the basin may have created highs and acted as localized volcanic sources.

As transgression continued, upper Spencer mudstones were deposited at middle to upper bathyal depths. Volcanic activity increased on the eastern edge of the basin. Mudstones grade eastward and upward into tuffs and flows of the eastern Willamette volcanic facies. ☐

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