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SMITH ROCK AND THE GRAY BUTTE COMPLEX

Also in this issue:

COLLECTING FOSSILS — COLLECTING THUNDEREGGS

EARTHQUAKE HAZARD ASSESSMENT IN OREGON

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

COVER PHOTO

Large-scale soft-sediment flexure preserved in bedded Smith Rock tuff (unit Tgs) along the ridge crest east of Smith Rock State Park. Unconsolidated tuff probably slumped or flowed slightly downslope, "wrinkling" the bedding. Article beginning on next page discusses geology of this central Oregon area.

OIL AND GAS NEWS

DOGAMI conducting rule review

The Oregon Department of Geology and Mineral Industries (DOGAMI) is conducting a tri-annual review of oil and gas rules under Chapter 632, Division 10. No changes are proposed, and written comments are solicited by the agency for review.

NWPA holds symposium and elects new officers

The Northwest Petroleum Association (NWPA) held its annual spring symposium in Leavenworth, Washington, during May. The geology of the Columbia River basin was discussed in both talks and field trips. Officers for the NWPA elected for 1989-90 are Dennis Olmstead, president; Barbara Portwood, vice-president; Nancy Ketrenos, secretary; and Todd Thomas, treasurer.

Ocean planning task force sets draft policy

The Oregon Ocean Resources Management Task Force met during May in Lincoln City. The Task Force has decided on an initial draft policy that prohibits oil and gas exploration and development in Oregon territorial waters. Research for the public domain would be allowed.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
426	LEADCO CC-Jackson 23-17 36-009-00255	SW¼ sec. 17 T. 5 N., R. 4 W. Columbia County	Application; 2,500.
427	DY Oil Neverstill 33-30 36-009-00256	SE¼ sec. 30 T. 6 N., R. 5 W. Columbia County	Application; 3,000.
428	DY Oil Forest Cav 13-6 36-009-00257	SW¼ sec. 6 T. 5 N., R. 5 W. Columbia County	Application; 2,000.
429	DY Oil Burris CC 24-8 36-009-00258	SW¼ sec. 8 T. 5 N., R. 4 W. Columbia County	Application; 3,000.
430	DY Oil Lane CC 24-5 36-009-00259	SW¼ sec. 5 T. 5 N., R. 5 W. Columbia County	Application; 2,000.

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CONTENTS

Smith Rock and the Gray Butte complex

*by Ellen Morris Bishop, Department of Geology, Oregon State University, Corvallis, Oregon 97331**

INTRODUCTION

There are plenty of places in Oregon where the scope of the earth and the puniness of man can be witnessed with resounding impact. Few of them are more abrupt in their message than Smith Rock and the adjacent gorge of the Crooked River.

From the beaver-hewn stumps on the torrent's bank, sheer walls tower 300 ft above a river hastening the Ochoco Mountains' winter to the sea. The vertical cliffs rise luminous, rosy and inviting in the morning light, yet stern and coldly foreboding in the late afternoon: mute, pale magenta parapets of challenging stone. The rolling growl of the water, a whisper of wind, and an echoing sense of remoteness from the frenetic outside world give us each a private interlude with forces monstrously and magnificently larger than ourselves.

But what built these ramparts? How long have they stood? And what bricks, what mortar bind them?

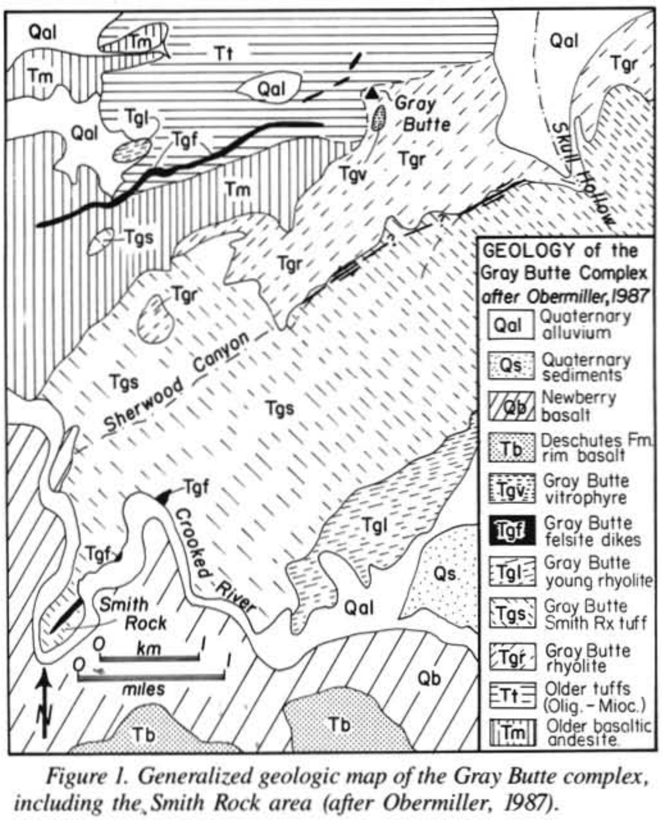

Figure 1. Generalized geologic map of the Gray Butte complex, including the Smith Rock area (after Obermiller, 1987).

Smith Rock is part of a larger eruptive center, the Gray Butte complex, that includes Gray Butte, Coyote Butte, Skull Hollow, and Sherwood Canyon. Its history is long and complicated, its details are still obscure, and its relatives and parents largely unheralded. But geologists are gaining in understanding of these spectacular outcrops.

Smith Rock and the rest of the Gray Butte complex, along with other silica-rich central Oregon eruptive centers including Cline Buttes and Powell Buttes, are located near the western end of the Brothers Fault Zone that bounds the northern edge of the Basin and Range province (Lawrence, 1976). These centers sit in a structural depression between the Blue Mountains old, accreted arc terrane and the Western and High Cascades volcanic arc.

To understand the geology of Smith Rock, the entire Gray Butte complex must be examined in more detail. The five igneous units that compose most of the Gray Butte complex, including Smith Rock, are identified by the name "Gray Butte" on the area geologic map shown in Figure 1. The Gray Butte units range in lithology from coarse olivine basalts and basaltic andesite to rhyolite and pyroclastic units. Work by Obermiller (1987) indicates that the complex is Miocene in age, erupted between 18 and 10 million years (m.y.) ago, which means that Smith Rock is younger than many geologists had previously thought.

BASEMENT OF THE GRAY BUTTE COMPLEX

To the north of the Gray Butte complex, Haystack Butte and Juniper Butte are composed in part of Eocene rocks of the Clarno Formation, mostly 40 to 48 m.y. in age. These rocks are mostly basalt and andesite flows and a few domes of more silica-rich composition. The Clarno Formation, which is intermittently exposed between the towns of Warm Springs, Prineville, Mitchell, and Fossil, is similar in lithology and chemistry to Cascade rocks. These rocks are calc-alkaline basalts and andesites of convergent margins, with mudflows and lahars suggesting the presence of at least a few stratovolcanoes.

Overlying the Clarno-age rocks at Haystack Butte, Juniper Butte, and as far east as the Painted Hills and the John Day valley are tuffs, rhyolites, and olivine basalts of the John Day Formation of Oligocene and early Miocene age. Ash found in this unit, which ranges in age from 37 to 19 m.y., probably came from volcanic vents in the vicinity of the Cascades (Robinson and others, 1984).

THE CLARNO AND JOHN DAY FORMATIONS AT GRAY BUTTE

The Gray Butte complex has previously been correlated with the John Day Formation on the basis of silicic lithologies and the presence of fossil leaves (Robinson, 1975). These rocks are exposed from Haystack and Juniper Buttes southward to Gray Butte.

According to Obermiller (1987), however, older rocks occur on the northern buttress of the Gray Butte complex. They consist of poorly exposed conglomerates and tuffs overlain by altered basalts and basaltic andesites, most probably of Clarno age. The area north

Figure 2. Flow banding in the Gray Butte rhyolite (unit Tgv in the geologic map shown in Figure 1). Photo field is approximately 8 in. across.

*Ellen Bishop has collected several of her *Time Travel* columns about the mountains of Oregon that appeared in the *Oregonian* and has published them in a spiral-bound book called *Tales the Mountains Told*. The book is sold in several central Oregon bookstores for $5.95. It is also available from her directly at Route 1, Box 248, Terrebonne, OR 97760, for $7 postpaid.

Figure 3. Rhyolite dike (unit Tgf) west of Gray Butte. View is to the east, and Gray Butte is in the background. Note horizontal columnar jointing in dike.

of Gray Butte also contains small patches of an ash-flow tuff and other rhyolite tuffs of the John Day Formation. Tuffs of probable early Miocene age are also present (Obermiller, 1987).

LITHOLOGIES OF THE GRAY BUTTE COMPLEX

Introduction

The rocks of the Gray Butte complex overlie and intrude the Eocene to Oligocene sequence. They are dominantly silica-rich.

Older rocks

Andesite flows apparently representing the earliest eruptive products of the Gray Butte complex occur as a relatively fresh basaltic andesite dated at 18.9 m.y. (K-Ar whole-rock) forming a broad apron north of Gray Butte (Obermiller, 1987).

The tuffaceous beds in these units largely appear to have been deposited in shallow water and contain a variety of plant fossils indicating that the climate, which was subtropical during the Eocene, gradually became more temperate (Ashwill, 1983; McFadden, 1986).

Geologists are unsure whether these rocks of early Miocene age are related to the same eruptive events that created Gray Butte and Smith Rock.

Gray Butte rhyolite

According to Obermiller's (1987) work, the earliest silicic unit of the Gray Butte complex is the Gray Butte rhyolite (Figure 2). This thick accumulation of flow-banded rhyolite occupies the northern portion of Gray Butte and is well exposed in Sherwood Canyon. It overlies tuffs of uncertain age that may be related to the Gray Butte complex. Its potassium-argon (K-Ar) whole-rock age is 17.8 m.y. The rocks show considerable flow folding, and a thin, glassy layer is present at the base of the unit. The absence of primary flow features such as lithophysae and spherulites and the presence of abundant axiolites and plastically deformed glass shards suggest that the Gray Butte rhyolite is a rheomorphic tuff, which is an ash-flow tuff that flowed after its emplacement (Obermiller, 1987).

The vent location for the Gray Butte rhyolite is not known. Little evidence, such as brecciation or local alteration and domes on Gray Butte itself, is known to indicate a vent location there. Pervasive epithermal alteration west of Gray Butte reported by Gray and Baxter (1986) and Rimal and others (1987) probably postdated eruption of the Gray Butte rhyolite unit. A wide, persistent rhyolite dike (Figure 3) west of Gray Butte may have fed some Gray Butte volcanism.

Smith Rock tuff

Next oldest unit of the Gray Butte complex is the Smith Rock tuff. It is this tan and red and green unit that forms most of what we think of as Smith Rock and the adjacent ridges, rising in knobs and spires, rhino horns, and broomsticks. It forms the spectacular buff cliffs along the north sides of the Crooked River in Smith Rock State Park, beloved of climbers and those who simply like to feel small (Figure 4). The Smith Rock tuff is a complicated unit consisting of multiple mud and ash flows and pyroclastic deposits.

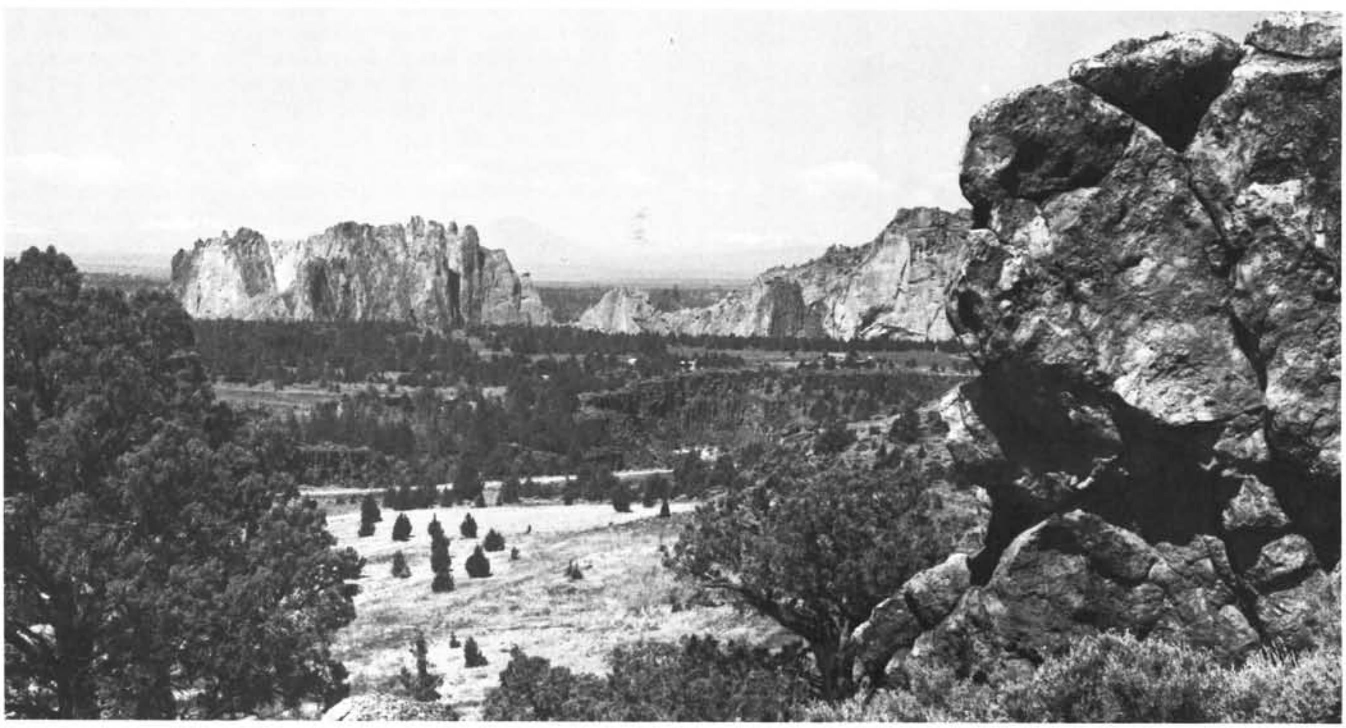

Figure 4. Canyon of the Crooked River winds through Newberry basalts toward Smith Rock State Park. Smith Rock tuff forms most of the high, light-colored cliffs.

The base of the Smith Rock tuff contains clasts of rhyolite and other rocks as well as organic debris including now-silicified tree trunks. Thin rhyolite flows are interbedded with tuffs and mudflows, suggesting that pyroclastic and flow volcanism occurred side by side.

Units of the Smith Rock tuff include mudflows, air-fall tuff, and muddy tuff flows. Angular fragments and autoclasts of rhyolite and tuffaceous material are common, although graded bedding is not, suggesting that material was not transported far and that the source (vent) of the tuffs is near Smith Rock itself (Figure 5). The Smith Rock tuff is bedded and, in some places, shows clear evidence of soft-sediment deformation in the form of soft-sediment folding (cover photo). All of the tuff is devitrified—the glassy ash and pumice fragments and some glassy matrix have been transformed by time and water into clay minerals.

The thickest part of the Smith Rock tuff is located about half a mile west of Smith Rock State Park. The thickness and greater level of alteration suggest that the feeder conduit may be buried there (Obermiller, 1987).

Figure 5. Angular clasts of rhyolite and pumice are abundant components of the porous Smith Rock tuff (unit Tgs). Much of the tuff exhibits subtle bedding. Dips are probably a primary feature of the tuff, indicating initial deposition on the steep slopes of a tuff cone (Obermiller, 1987).

The Smith Rock tuff cone

Smith Rock itself may represent part of a tuff cone (Obermiller, 1987)—a low, sloping edifice composed of silica-rich lava that was transformed into hot, fragmental tuffs upon explosive eruption into a wet environment. Tuff cones can be respectable in size: Diamond Head in Hawaii rises as much as 770 ft above the ocean and is more than a mile in diameter. Or they can be small, pocket-sized volcanoes similar to Fort Rock. An as-yet-unanswered question is whether the matrix of Smith Rock was welded together as a hot, sticky, pasty mass immediately after the eruption or was cemented slowly together after deposition. The answer to this question, which requires study with microscopy, will determine whether, technically, Smith Rock is an ash (welded) or tuff (cemented) cone.

Other flow rocks of the Gray Butte complex

Several other flows of diverse compositions are present in the Gray Butte complex. A thin, lithophysal rhyolite flow is found in the east-southeast part of the Gray Butte complex, overlying the Smith Rock tuff (Figure 6). It is pink to red and displays good flow banding. This flow is overlain by more mudflow deposits and tuffs so probably is contemporaneous with the Smith Rock tuff.

Thin flows of olivine basalts and basaltic andesites must have been erupted during this time as well. They are exposed on the north side

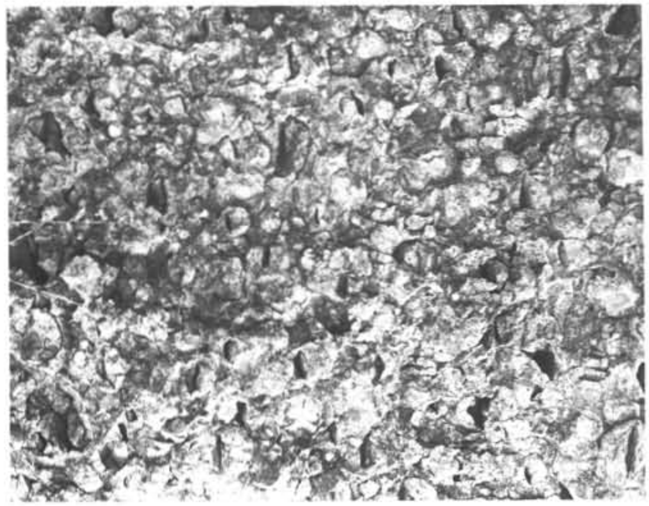

Figure 6. Lithophysae in rhyolite (unit Tgl) east of Smith Rock State Park. These 1- to 2-in. spherical cavities and blisters result from the entrapment of gas (mostly steam and carbon dioxide) within a cooling rhyolite flow. If filled with opal or chalcedony deposited by hot water within the flow, they would be thundereggs.

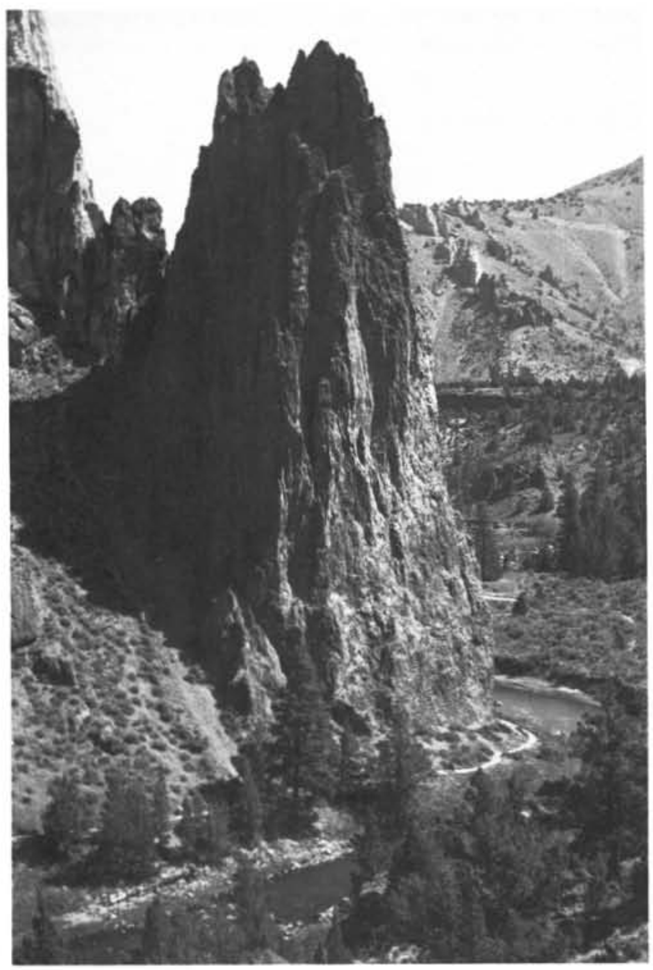

Figure 7. Microfelsite dike (dark rock) (unit Tgf) rises from the Crooked River at Smith Rock State Park. Bench in middle ground is Newberry basalt (unit Qb). Light-colored rocks in background are Smith Rock tuff (unit Tgs).

of the Gray Butte complex along with several basaltic dikes that may have fed the flows. The age obtained for these flows is 17.4 m.y., based upon K-Ar whole-rock measurements (Obermiller, 1987).

The Smith Rock microfelsite

Possibly the youngest unit of the Gray Butte complex is a microfelsite dike of rhyolitic composition that forms a distinctive, red, hard, and brittle edifice on the north side of the Crooked River (Figure 7). This narrow, intrusive conduit carried rhyolite magma in near-vertical flow to be erupted somewhere above the present Smith Rock. The microfelsite—seen on fresh surfaces as a light-colored, finely crystalline rock of rhyolitic composition—exhibits good vertical flow banding in some locations and has a chilled margin against the Smith Rock tuff. The dike clearly was emplaced prior to complete solidification and dehydration of the tuff, because less than a foot from the dike, the contact-baked, porcelainlike tuff developed strong vesicularity, as though trapped water had boiled in a cool but unconsolidated country rock. On the west side of Smith Rock, the dike seems mingled with the tuff, suggesting that it intruded in anastomosing, enveloping style, feathering into the surrounding rock.

Summit vitrophyre

The youngest dated rock of the Gray Butte complex is a glassy rhyolite, a texture called a "vitrophyre," nestled into the southwest side of Gray Butte's summit. Obermiller (1987) obtained a K-Ar whole-rock age of 10.7 m.y. for this unit. However, its extremely limited extent and its high content of altered glass make this whole-rock age somewhat suspect.

If this date is spurious, then the eruptive history of the Gray Butte complex was brief, perhaps spanning less than 2 m.y.

The rimrock basalts

The last volcanic episode written in the rock record exposed along the Crooked River is the eruption of voluminous basalts. They are part of the Deschutes Formation, flowing from the low shield volcanoes to the west—Green Ridge, Squaw Back Ridge, and others—about 4.5 m.y. ago. They lapped up upon a silicic highland—the eroded remnants of the Gray Butte complex, then standing slightly higher than they do at present. The early Crooked River canyon was eroded along the contact. About 1.2 m.y ago, this canyon was filled by flows from Newberry volcano. These flows form the dark cliffs currently seen along the Crooked River near Smith Rock State Park (Figure 8).

PETROLOGY AND GEOCHEMISTRY OF THE GRAY BUTTE COMPLEX

Where did this silica-rich magma come from? How was it generated? For the answers to these questions we must turn to petrology and geochemistry.

According to major-element analyses (Obermiller, 1987), the Miocene basalts associated with Smith Rock are tholeiitic in composition (Table 1). Their content of TiO_2 (usually >1.5 weight percent) is anomalously high for arc-related volcanics, however, and may be related to their eruption in a back-arc extensional environment east of the Cascades.

Generally, these basalts and basaltic andesites belong to the regime of early island arcs and are chemically distinct from the mid-

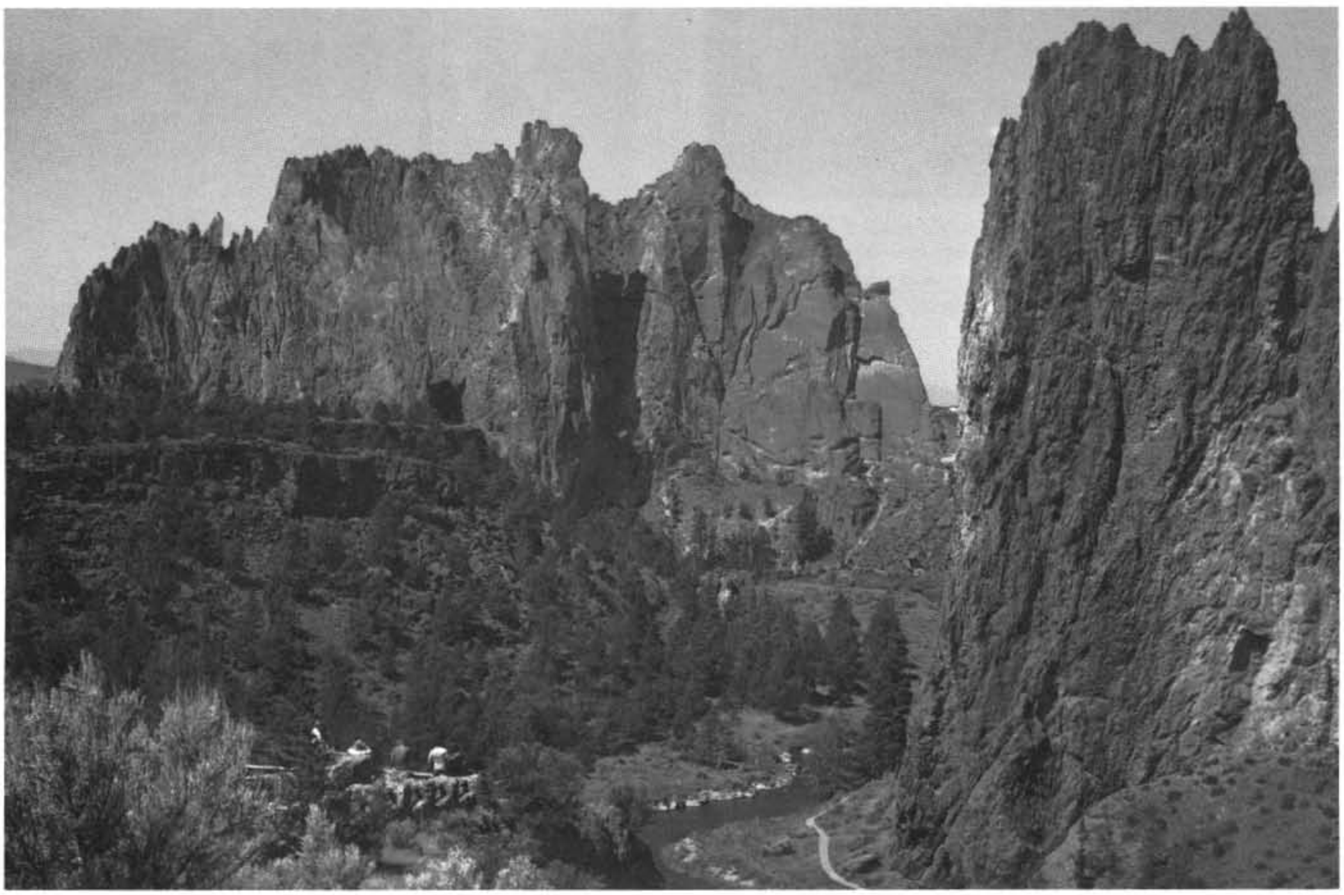

Figure 8. Basalts from Newberry volcano south of Bend flowed down the Crooked River about 1.2 million years ago (Smith, 1986). These intracanyon flows (unit Qb) now form the dark, columned cliffs on the south side of the Crooked River at Smith Rock State Park. Felsite dike (unit Tgf) is exposed at right of photo. Other rocks are predominantly Smith Rock tuff (unit Tgs). View is to the west.

Table 1. *Major- and trace-element analyses of rocks from the Gray Butte complex. Data from Obermiller (1987).*

Sample no. Rock type	24 Basalt	SR-B-1 Bas. andesite	SR-RH-4 Rhyolite	SR-RH-1 Rhyolite	SR-T-5 Tuff
SiO_2 (wt.%)	50.13	57.86	82.99	77.75	76.36
TiO_2 (wt.%)	2.29	1.79	0.17	0.20	0.28
Al_2O_3 (wt.%)	15.36	14.58	8.63	12.11	13.36
FeO* (wt.%)	11.65	11.13	1.78	1.35	0.63
MnO (wt.%)	0.20	0.21	0.03	0.01	n.d.**
MgO (wt.%)	6.68	2.63	n.d.**	n.d.**	n.d.**
CaO (wt.%)	9.96	6.41	0.18	0.23	0.13
Na_2O (wt.%)	2.67	3.86	2.50	4.05	0.82
K_2O (wt.%)	0.38	0.81	3.75	4.40	8.47
P_2O_5 (wt.%)	0.63	0.76	0.02	0.02	0.04
Total	99.95	100.04	100.05	100.12	100.09
Ba (ppm)	232	335	658	824	944
Rb (ppm)	28.00	33.40	111	143	342
U (ppm)	n.d.**	n.d.**	3	4	5
Nb (ppm)	17.00	20.00	43	63	59
Zr (ppm)	174	207	349	412	465
$^{87}Sr/^{86}Sr$	0.7042	0.7040	0.7101	0.7096	0.7131
$^{143}Nd/^{144}Nd$	0.51280	0.51295	0.51287	0.51286	0.51289
Age (K-Ar whole-rock in m.y.)	18.9 ±0.5	17.4 ±0.9	17.8 ±0.4	n.d.*	15.4 ±0.3

* FeO = FeO + Fe_2O_3
** n.d. = no data

dle Miocene basaltic rocks, the Prineville chemical type of Uppuluri (1974) and the Bear Creek basalts of Goles (1986), that form the ridges east of Lone Pine Flat and that were erupted perhaps 3 m.y. later than the Smith Rock basalts.

Trace-element data corroborate this diagnosis (Obermiller, 1987). Rare-earth element plots of basaltic rocks from the Gray Butte complex (and other central Oregon silicic centers, including Powell Buttes and Cline Buttes) show light-rare-earth enrichment of 70 to 150 times chondrite (Figure 9), with Ce/Yb ratios of about 10. Such enrichments are slightly greater than most tholeiitic island-arc basalts.

The rhyolites and tuffs of the Gray Butte complex show similar signatures (Figure 9). They are peraluminous and corundum normative (Obermiller, 1987). They have substantial negative europium anomalies, suggesting that they were derived by fractionation (Obermiller, 1987) or that oxidation and dissolution have altered the original europium content of the rock. There is excellent evidence for the presence of an epithermal system at depth beneath Gray Butte, with the development of silica caps and brecciated zones near the western base of Gray Butte (Gray and Baxter, 1986). However, this hydrothermal circulation may not have substantially altered the surface rocks from which isotopic samples were taken.

THE ORIGIN OF THE GRAY BUTTE COMPLEX

According to Obermiller (1987), the best model for the origin of the Gray Butte complex basaltic andesites and rhyolites is fractionation of basaltic parental magmas of similar composition to the associated olivine-bearing tholeiitic basalts. The spectrum of basaltic

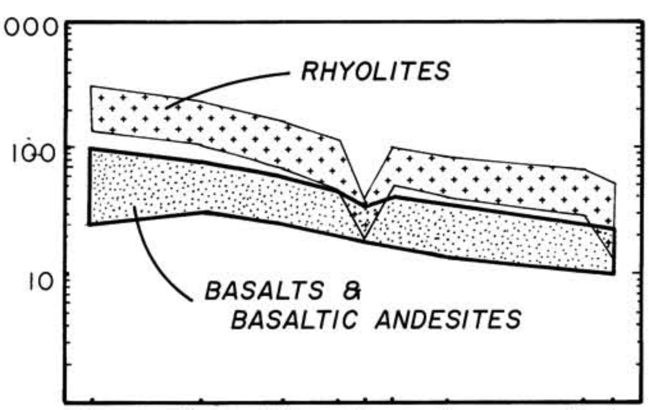

Figure 9. Rare-earth-element plots for rocks of the Gray Butte complex (after Obermiller, 1987).

compositions can be approximated by Rayleigh fractionation of varying amounts of olivine and plagioclase, with lesser clinopyroxene fractionation. Models of derivation of rhyolites by partial melting of altered or fresh basalts resulted in lower alumina contents than present in Smith Rock rhyolites. Rayleigh fractionation of evolved olivine tholeiites can produce most rhyolitic compositions at Smith Rock and Gray Butte (Obermiller, 1987). However, isotopic data suggest that considerable crustal contamination affected the Gray Butte complex. Values for $^{87}Sr/^{86}Sr$ ratios of basalts beneath Gray Butte range from 0.7036 to 0.7072, with most values in the 0.704 range (Obermiller, 1987)

Rhyolites have considerably higher $^{87}Sr/^{86}Sr$ ratios. The Gray Butte rhyolite yielded a value of 0.7101, and values for other rhyolitic rocks vary from 0.7068 to 0.7128 (Obermiller, 1987).

The Gray Butte complex samples have Nd and Sr ratios that plot to the right of the oceanic correlation line and in a field of lower Nd than island arcs, including the Cascades (Figure 10). Contamination by either seawater-altered oceanic rocks or continental detritus or the presence of an enriched magma source could cause this result. Lead isotopic data also suggest a crustal component in Gray Butte complex magmas (Figure 11). These plots indicate substantially greater upper crustal involvement in the Gray Butte complex than in the Cascades.

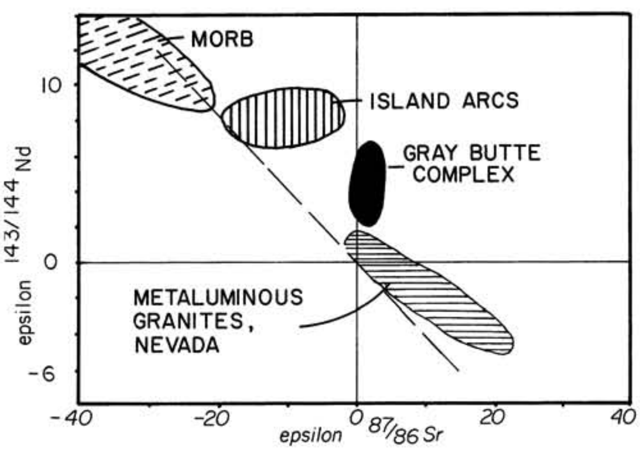

Figure 10. Plot of $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic ratios. Gray Butte complex samples show substantial evidence of upper crustal contamination (after Obermiller, 1987). Granite data are from Farmer and DePaolo, 1984. Diagonal line is trend for oceanic rocks. MORB=mid-oceanic ridge basalt.

IMPLICATIONS FOR THE TECTONICS AND CRUSTAL EVOLUTION

The nature of the involved crust is a bit problematic. No pre-Tertiary basement is known in this immediate area, and all indications are that the Deschutes basin upon which the Gray Butte complex is built is a thinly crusted product of back-arc extension and Basin and Range rotation (Smith, 1986; Obermiller, 1987). Although a single fusulinid-bearing limestone cobble was reported from the Smith Rock tuff (Thompson and Wheeler, 1942), it is likely that this rock originated in Crooked River gravels transported from the Grindstone terrane, rather than being a xenolith transported upward in Smith Rock tuff (Obermiller, 1987).

However, the isotopic evidence for some degree of upper crustal contamination of the Gray Butte complex is substantial. It suggests that Paleozoic/Mesozoic accreted terranes exposed in the Mitchell and Izee areas to the east and southeast, respectively, and also exposed along the Hay Creek anticline in the Hay Creek canyon area only 12 mi to the northeast, may also extend under the Gray

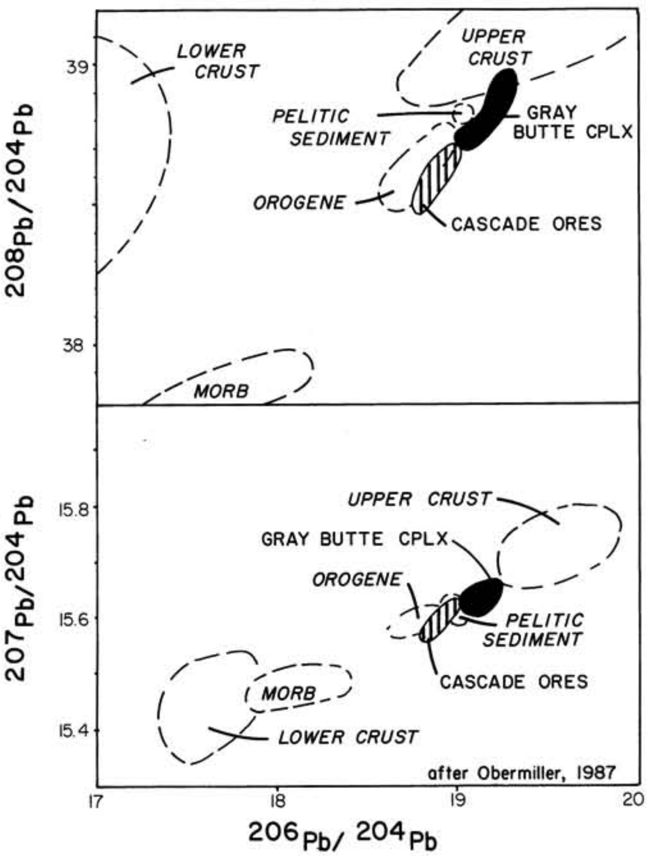

Figure 11. Plot of lead-isotopic ratios for the Gray Butte complex (after Obermiller, 1987). Gray Butte samples show evidence for substantial upper crustal contamination and plot on a mixing curve between upper crustal rocks and island-arc basalts.

Butte area. Alternatively, tuffaceous rocks and basinal deposits of the Clarno and John Day Formations may have contributed to or produced silicic shallow crustal melts in response to basaltic magmatism related to back-arc and Basin and Range-related extension. The probable oceanic nature of the first alternative and, likely, small changes from oceanic isotopic ratios suggest that the second alternative—contamination with altered Clarno and John Day volcanic and volcaniclastic materials—is the better model, although it is less than ideal.

ACKNOWLEDGMENTS

Most of the information in this paper is from the thesis of Walter Obermiller (1987). This paper's conclusions, however, are those of the author. Review by Jerry J. Gray, Oregon Department of Geology and Mineral Industries, is gratefully acknowledged.

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New report on bentonite in Oregon released

A comprehensive report on bentonite 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 development of bentonite as an industrial-mineral resource in Oregon's economy.

The study concludes that exploration opportunities for commercial bentonite and the potential for large deposits exist in Oregon. It also indicates that there are West Coast and Pacific Rim bentonite markets that Oregon could supply. Preliminary analyses show that Oregon bentonites have a wide variety of physical properties that could serve a wide spectrum of industrial uses.

Bentonite in Oregon: Occurrences, Analyses, and Economic Potential, by DOGAMI geologists Jerry J. Gray and Ronald P. Geitgey and DOGAMI geochemist Gary L. Baxter, has been published as DOGAMI Special Paper 20.

The report consists of a 28-page text that describes bentonite as a rock and a commodity; the bentonite industry and trade, including exports; Oregon's bentonite industry and the resource potential of the state; and the laboratory testing of 152 samples collected for this study. The text is accompanied by three separate plates, one map and two tables: The compilation geologic map shows sample locations and geologic units deposited in basins in eastern and parts of western Oregon. One table lists tonnages of domestic uses and exports of bentonite and fuller's earth in 20 use categories and over a period from 1975 to 1986. The second table describes all samples, their locations, the nature of the sample sites, and the results of physical and chemical tests and X-ray diffraction mineralogy.

The new report, DOGAMI Special Paper 20, is 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 is $6. Orders under $50 require prepayment.

Collecting fossils in Oregon

*by Melvin S. Ashwill, amateur paleontologist, 940 SW Dover Lane, Madras, Oregon 97741**

INTRODUCTION

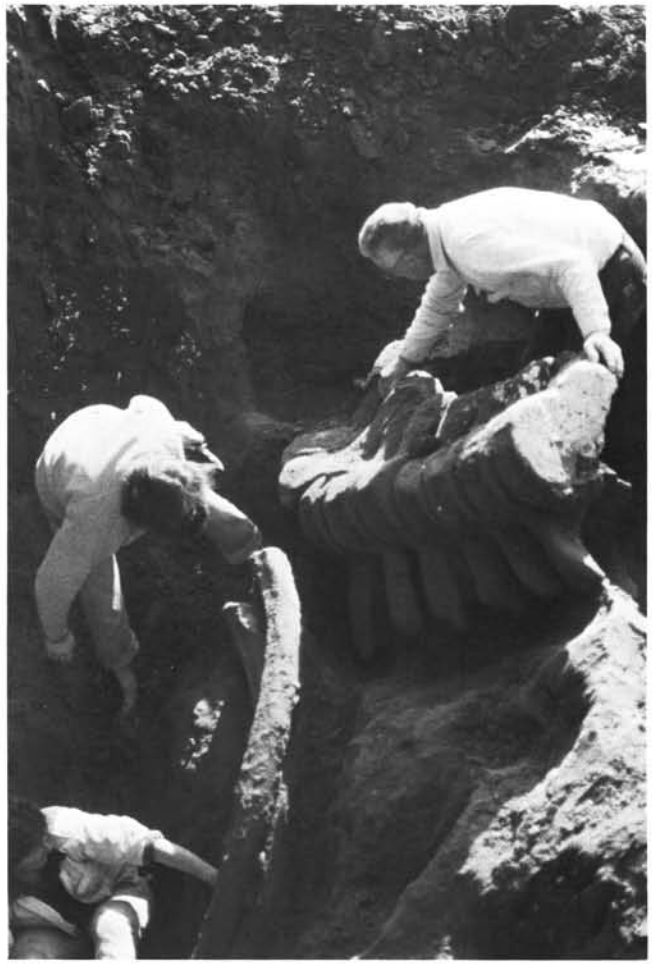
Hanging on my study wall is a clock I have made from a flat slab of rock that has on its surface a magnificent large fossil leaf from an ancient sycamore tree. Of course, the clock is a delight to me, yet each time I look at it, I experience a tinge of regret because I know that this lovely and significant fossil will never be where it properly belongs—in a research collection to record the development of the sycamore family. It is not now suitable for such a collection because no one knows for sure its age or where it was found. An old friend collected this and many other quality specimens but did not put any identifying marks on this one. At his death, his son gave me several pieces from the collection. I think that I know where this one came from, for I know his collecting habits, and the rock matrix is familiar to me. In the field of science, however, "I think," "probably," and "I guess" are enough to fling a shadow of doubt that reduces evidence to worthlessness. Therefore, this beautiful fossil is reduced to being "only a curiosity." Lesson: Immediately upon collecting a fossil, number and reference it in some permanent manner so that locality and other important information pertaining to it are not lost.

A fossil collection can be a source of pleasure in many ways. The specimens themselves are beautiful. As evidence of evolution as well as changing ecological conditions through time, they provide food for thought. The collecting process itself gets the collector outdoors to many different areas and provides healthful exercise. Beyond these purely selfish concerns, however, your collection can serve a useful purpose. If you are careful as you collect and identify your fossils, if you keep good records, and if you share your information with other fossil collectors—both amateur and professional—as well as with others interested in learning about paleontology, your fossils can also serve to advance knowledge. This article tells you how to get started in fossil collecting—and how your fossils may be useful to others.

BASICS OF FOSSIL FINDING

If all of the readers of this article were to start driving their cars at the same time, and then if they all were to stop their cars at the same moment, get out, and spend two hours digging for fossils wherever they happened to be, Las Vegas oddsmakers should be able to make a lot of money by betting that none would find a fossil—even in Oregon, one of the premier fossil grounds of the world. Yet, armed with proper knowledge, any person living in Oregon could probably drive to a fossil site in less than an hour from his or her home. A paleontologist friend from Indiana is envious. "Why, you could ride a bicycle from your house to this site," he exclaimed of a locality near my home.

So, how do you locate fossils? First off, don't waste your energy digging for fossils unless you have been given good reason to believe there are some at hand. In Oregon, you can rule out huge expanses of two kinds of geologic environments. You can be fairly certain, for example, that you will find no fossils in lava rock. It should be noted, however, that most rules have exceptions. For instance, Lava Cast Forest near Bend has fossil impressions of tree trunks that were buried in lava, and near Blue Lake in Washington, a mold of the bloated carcass of a rhinoceros exists in a basalt flow. Furthermore, areas of topsoil, the loose, fine-grained dirt that collects in valley floors, are not prime sites. On rare occasions, topsoil preserves fossils, but generally it does not. The processes that move a fossil from bed rock into topsoil usually also reduce the fossil to dust—or at least to fragments.



Pleistocene fossil whale being excavated near Port Orford in Curry County under the supervision of Dave Taylor, Northwest Museum of Natural History Association. Shown from bottom to top of photograph are Meredith Myllenbeck, Lana Stricker, and Clair Stahl.

So, what are the likely areas? Wood, leaves, flesh, bones, and even teeth, if exposed to the elements, will decompose with time. It is no surprise, then, that most well-preserved fossils are found in rocks that originally were a mud that protected the organic material from oxygen and therefore bacterial decay. If the remains survive this initial step of burial, minerals in ground water may permeate and harden them. Fine-grained sandstone (or siltstone, mudstone, or shale) is one of the fossil-hunter's favorite rocks. For marine fossils, another likely tomb is limestone. Most limestone is composed of remains of sea creatures. The third promising type of host material in Oregon (mainly central and eastern) is what was originally light-colored volcanic ash that rapidly buried plants and animals with thick deposits.

Because of the flat structure of minerals in fine-grained mudstones and shales, these rocks often split into flat slabs. A paleontologist's right foot

*Mel Ashwill maintains a private fossil museum behind his home, which is at the northwest corner of the intersection of Dover Lane and Highway 97 about 2 mi south of Madras. He is willing to show the museum to interested persons or groups by phone appointment only. His phone number is (503) 475-2907.

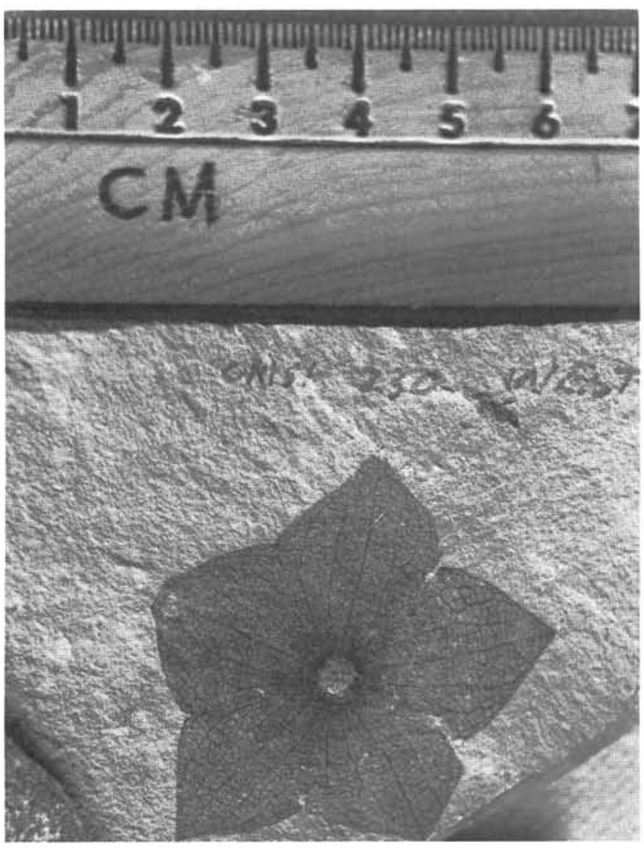
automatically eases off the gas pedal when he or she passes a roadside exposure of platy, sedimentary rocks. Many are fossiliferous.

Diligent searching in favorable areas will, at length, probably lead to the discovery of fossils. However, there is a short cut used by most fossil finders. Somebody shows or tells them where to find the quarry (pun intended)! Other collectors know of likely sites and are willing to share their knowledge. Hunters, farmers, ranchers, and geologists all spend a lot of time on foot in out-of-the-way places. They frequently locate new areas and often will, if asked, help the paleontologist. Additionally, as geologists publish the results of their field work and often give exact locality coordinates, time spent reading geological papers will often produce helpful information for you. A two-line mention in a geological paper can take you to an exciting find.

HELPFUL PUBLICATIONS

There are even books that will direct you to fossil sites. A reference, informally known as the "Blue Book" among fossil collectors, is entitled *Fossils In Oregon*. Edited by geologist Margaret L. Steere, the 227-page book was published by the Oregon Department of Geology and Mineral Industries (DOGAMI) as Bulletin 92 and can be purchased from its main office (editor's note: see address on inside front cover of this issue. Also, be advised that the glue binding the book is not very durable, so that the book, while filled with useful information, tends to fall apart easily). The book contains directions to and descriptions of fossils from more than 35 fossil locations in Oregon. It is copiously illustrated.

Two other books on Oregon paleontology are indispensable to anyone interested the state's fossils. The wife-and-husband team of Elizabeth L. and William N. Orr (University of Oregon paleontologist) authored both the *Handbook of Oregon Fossils* (1981) (available at private bookstores and from the authors at P.O. Box 5286, Eugene, Oregon 97405) and the *Bibliography of Oregon Paleontology, 1792-1983* (1984) (available as Special Paper 17 from DOGAMI).



*Flower of extinct tropical vine (*Holmskioldia sp.*) of Eocene age. Fossil was collected from the West Branch Bridge Creek near Mitchell.*

Mastodon tooth taken from bog deposits near Tualatin, Oregon. Photo courtesy of the Oregon Museum of Natural History.

Although it does not contain precise locality directions, the 285-page *Handbook of Oregon Fossils* is a gold mine of well-organized information. Generalized discussions of fossil plants, pollen, invertebrates, trace fossils, arthropods, fresh-water fish, birds, marine vertebrates, and land vertebrates include many illustrations that will help you in identification of your fossils. The bibliography at the end of the book can help you find new localities to explore.

Bibliography of Oregon Paleontology, 1792-1983, also by the Orrs, is a compilation of references containing information about Oregon fossils up to 1984. Its 82 pages list more than 1,200 references, most of which will help guide the collector to at least one specific locality.

OTHER INFORMATION SOURCES

Visits to museums can lead you to more information. Many small local museums exhibit a few local fossils and often include the name of the collector. Natural history exhibits will help familiarize you with what is available and what you should be looking for. You can ask other collectors about associations or societies where you can meet people with interests similar to your own. You can subscribe to local or state publications such as *Oregon Geology* that publish papers related to local paleontology. If you are really serious about your fossil collecting, you can contact local community college geology teachers or university professors for information about fossil-collecting sites.

PROSPECTING TECHNIQUES

A few paleontologists publish such complete locality directions, including photographs, that they enable the collector to drive or walk directly to the site and begin collecting. More commonly, however, directions will consist of coordinates (township, range, section, and quarter section) and perhaps a brief description of strata above and below the site. This will get the collector to within about an eighth of a mile of the locality, still leaving a vast area to be covered in the search.

A common technique followed by collectors in searching the terrain for a fossil site, which may be only a small exposure, is similar to the process often used by precious-metals prospectors. Unless it is known that the exposure is actually a stream bed, it is better to search the sides of the hills a little bit above the valley floor. A fossil-bearing ledge uncovered by erosion in the valley bottom is likely to be covered by topsoil to a considerable depth. On a sidehill site, as the fossils weather out, they are moved downslope along with other rocks and soil. On their journey to the bottom of the hill, the fossils are constantly being reduced by weathering and abrasion to smaller and smaller pieces and eventually, of course, are no longer recognizable as fossils. The fossil hunter needs to traverse back and forth on the hillside, starting just above the valley floor, and gradually climb the hill while scanning the ground closely.

Usually, the first sign of the object of the search is a small fragment, so the collector must closely examine the surface of promising rocks. What should one look for? Usually regular shapes or lines; smooth surfaces and contours; curves rather than jagged edges; contrasting color patterns on rock surfaces; and repeating segments such as ribs, growth lines, and leaf veins. Actually, any rock that stands out as being somehow different from the other local rocks bears a second look. A previous excavation pit, though grassed over and partially filled, often tattles as to the location of the site. In the case of vertebrate fossils, teeth are the hardest components of the skeleton, and smaller fragments may have settled to the bottom of the drainage area. Color is often used to distinguish fossils from rock matrix. Cape Blanco is so named because of the white Pleistocene shells exposed there. Vertebrate fossils of calcium phosphate often preserve with a typical carmel brown or even bluish color.

After the first fragmentary find, the collector needs to slowly work uphill, following a trail of increasingly larger fragments to the fossil-bearing outcrop, the bonanza! Sometimes the outcrop itself is covered by topsoil, and the only evidence as to its location is the fact that at a given point, the uphill trail of fragments gives out. Digging is now warranted. Fossil-bearing outcrops may be found at any point on a hillside, but it is remarkable how often they occur at the brow of a knob—and, in Oregon, how often they occur in strata just below a lava flow.

Light conditions can affect the visibility of fossils in the field. Low, slanting light seems to emphasize the flat and curved surfaces of the specimens. Morning and evening hours provide this condition. How serendipitous it is that these hours also allow one to avoid the heat of the day.

"You find what you are looking for" is a truism that is abundantly illustrated in fossil collecting. Earlier large-vertebrate collectors bypassed some areas rich with small specimens, eggs, and nests. They were looking for large bones and skulls, and they found them. Now that the significance of the smaller items is recognized, they too are being recovered in quantity.

Another "old geologist" saying is, "I wouldn't have seen it if I hadn't believed it." A friend who is an avid and very successful big-game hunter says he envies me because in all his life he has never recovered a single artifact or fossil, while I have found many. When we hunted together, he always got the game, and I always came away with a few interesting rocks in my pockets. When I guide a class to a fossil site, members often express puzzlement as to just what it is for which they should be looking. My verbal descriptions help a little, but once the students have actually seen a specimen, others usually turn up, with no more help needed.

HOW TO COLLECT

Only rarely does a fossil site produce quality material lying loose on the surface of the ground. When such a place is located, however, collecting is easy, and few tools are needed. A backpack or sack to carry the specimens, some newspaper for wrapping them, a permanent-ink felt-tip pen for marking them, and a geologists' hammer will do nicely.

More commonly, light digging is necessary. Removing partially visible specimens from exposed ledges will require some sort of sharp-edged bar or chisel and possibly even a shovel and pick. You

Fossil skull of a Pleistocene bison taken from a bog near Salem. Photo courtesy of the University of Oregon Museum of Natural History.

Hugh Wagner works to excavate a juvenile rhinoceros jaw from the wall of Blue Basin in the John Day Fossil Beds National Monument. Inches beneath the crumbly, weathered surface, the rock is hard, making excavation of the brittle fossils a delicate task. Photo courtesy of U.S. National Park Service.

will note that whisk brooms, fine chisels, knives, plaster of Paris, and surveying equipment have not been mentioned. There are times, of course, when all of the above, and more, are needed.

If you are lucky enough as an amateur to come across a really significant find, such as a partial skeleton fossilized in place, for example, that might call for more sophisticated methods of collecting, the best service you can do for yourself and for science is to (1) enjoy your find ("Oh," "Wow," and "Just look at that," are in order); (2) write down directions to your find and mark the location with something such as a handkerchief on a bush or spray paint on a rock so that it is easily visible; (3) photograph the exposure; and (4) refer your information to a professional paleontologist. It is unlikely that you will get everything right if you try to remove the fossil yourself. Without a doubt, the professional who comes out to collect the specimen will welcome your help in its recovery. You will get the thrill of collecting and learn how it is properly done, and the fossil will be removed intact with the proper documentation. More importantly, the orientation of a fossil in the matrix may be a significant piece of research information. The fossil should not be disturbed until this is recorded.

Where do you find the professionals? There are at least eight actively working in the state of Oregon: William Orr, Department of Geology, University of Oregon, Eugene; Guy Rooth, Department of Geology, Western Oregon State University, Monmouth; David Taylor, Northwest Museum of Natural History Association, Portland; Richard Thoms, Geology Department, Portland State University, Portland; Theodore Fremd, Paleontologist, John Day Fossil Beds National Monument, John Day; Jane Gray, who specializes in the study of pollen and spores (micropaleobotany), Departments of Geology and Botany, University of Oregon, Eugene; Gregory Retallack, an expert on paleosols (fossil soils), paleobotany, and fossils in general, Geology Department, University of Oregon, Eugene; and A.J. Boucot, who has an extensive background of work with marine invertebrate fossils, Departments of Geology and Zoology, Oregon State University, Corvallis.

WORD OF WARNING

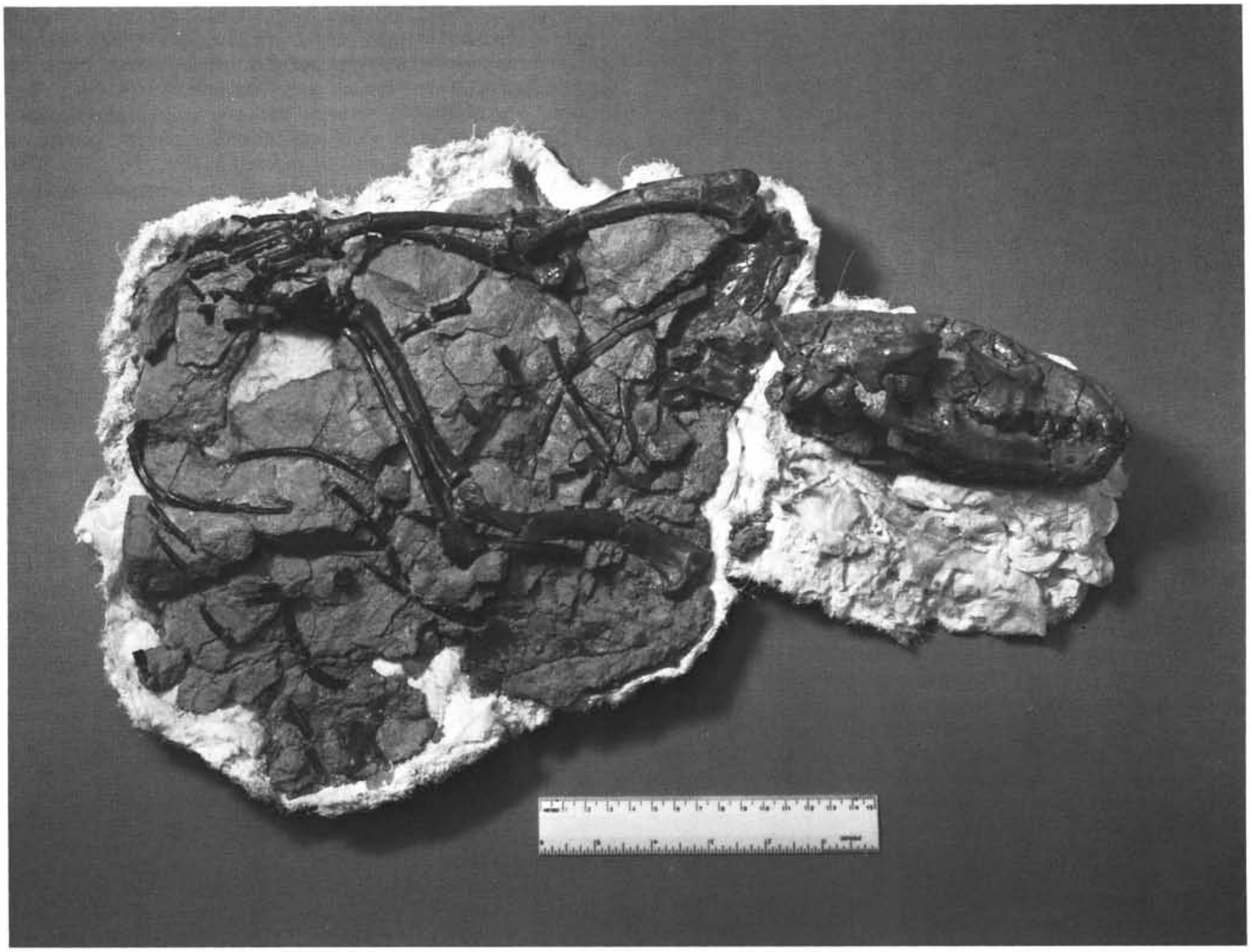
Do not accidentally walk on fossils. If you find fossil fragments on the surface of the ground, carefully scan the area before doing any more prospecting. Small vertebrate fossils are often carelessly destroyed by foot crushing.

HANDLING FOSSILS

Your first charge, after recovering fossils, is to return them to your home without damaging them. Careful and tight wrapping in newspaper is the usual method of protection. Before you wrap them, however, you should mark them with the location. In your laboratory area, if you have unmarked boxes of fossils from more than one site, being sure of the source is a problem. Take a permanent-ink felt-tip pen with you on your collecting trips. Mark specimens directly, and again mark the outside of the box or sack before leaving the site.

Large museums hire technicians, called "preparators," who do the demanding detailed work of trimming, cleaning, and repairing fossils. In your jack-of-all-trades capacity, however, you will do this. In the case of vertebrate and invertebrate fossils or petrified wood, this usually means removing the fossil completely from the matrix. An exception might be when you plan to exhibit the fossil partially exposed but remaining attached to its rock matrix, which is an effective technique. In either event, exposure of the fossil demands careful and sometimes tedious work. In the case of vertebrate fossils, the amateur would do well to consult a professional paleontologist before tackling this specialized task. Much of such a job is often done with sharp metal edges, such as small chisels, picks, knives, vibrator tools, engraving tools, and drills. Water or other solvents are sometimes a help in softening the rock. Trial and error will help determine which of these tools to use, and advice of other collectors is an aid. In the case of leaf imprints on rock, trimming away

William N. Orr, paleontologist at the University of Oregon, discusses a fossil mammoth tusk at the University of Oregon Museum of Natural History. Listening is Dolph James, former Director of the Eugene, Oregon, Branch of the Oregon Museum of Science and Industry. Mammoth tusk is from Pleistocene gravels near Roseburg.



*Fossil dog (*Mesocyon sp.*), latest Oligocene/early Miocene, from the Turtle Cove Member of the John Day Formation at the John Day Fossil Beds National Monument. Specimen was collected in 1982 by Hugh Wagner. Note plastic jacket surrounding fossil. This is a good example of an extremely fragile specimen that required full laboratory facilities to prepare, identify, and study. Photo courtesy of U.S. National Park Service.*

excess matrix is usually the main task and is accomplished with hammer and chisel, pliers, vises, and rock saws. Leaf fossils with a relatively soft matrix can be trimmed on a table saw with a masonry blade. Harder specimens must be worked with a lapidarist's diamond-edged saw, using water, not oil, as a coolant.

Specimens that have been coated with shellac or similar clear finishes are often seen on display. You should be aware that such treatment often enhances the contrast and appearance of the fossil but can detract from its scientific usefulness. When you put such a specimen under a microscope, you have to look through the coating, and some detail is lost. Some fossils are so highly fractured that it is necessary to coat and impregnate the material with bonding agents to hold the pieces together. In such cases, you must be careful that surface details are not obscured. A dilute solution of polyvinyl acetate in acetone is superb for soaking a fossil and binding it together without leaving a thick residue on the surface.

LABELING AND RECORDING

In order to be able to positively relate a fossil to its locality, an organized form of marking and recording is needed. Commonly, museums and collectors alike use permanent ink on a small spot of white paint to mark specimens in a type of shorthand code. Typewriter "whiteout" is sometimes used for this purpose but may flake off unless covered by shellac. Each of your localities should be given a number that is recorded in a notebook along with a complete set of locality directions. This locality number is marked on the appropriate specimens. It should be prefixed with the initials of the collector or the institution housing the collection. An example is "UO-1407," which is University of Oregon Museum of Natural History locality number 1407. If the specimen is an important item, such as a type specimen cited in the literature, it should also be marked with a catalog number.

As you record your locality information, photographs, written directions, and maps are helpful. Indispensable are geographic coordinates. To determine the coordinates, find the site on the largest scale topographic map available and mark it on the map with a small "x" or dot. This will enable you to determine which quarter of which section it occupies. The coordinates consist of (1) the quarter of the quarter section in which the site is located, if the map scale permits such precise location; (2) the quarter section in which the site is located; (3) the section number; (4) the township number; and (5) the range number. An example is SW¼NE¼ sec. 10, T. 12 S., R. 18 E., which means the southwest quarter of the northeast quarter of section 10 of Township 12 south of the Willamette Base Line and in Range 18 east of the Willamette Meridian.

*This magnificent specimen is a fossil scallop (*Patinopecten propatulus *[Conrad]) from the Miocene Astoria Formation at Newport, Oregon. Photo courtesy of the University of Oregon Museum of Natural History.*

IDENTIFICATION

Once you have collected and prepared your specimens, they should be classified and identified. Identification of some specimens, such as those of new species, for example, or those whose features are not readily assignable to a particular taxon, may require the resources of our professional allies.

The common genera and species can often be identified by comparison to either the illustrations and descriptions in the helpful volumes previously mentioned or by referring to special studies in published papers found in science libraries at major universities in the state.

Two other publications are also helpful in your identification of fossils. *Fossil Mollusks of Coastal Oregon*, by Ellen James Moore (1971), is indispensable to anyone collecting invertebrate fossils of the area. Its 64 pages are crammed with excellent photographs of specimens. Moore's book is published by the Oregon State University Press, Corvallis, and may also be found in science libraries. *Common Fossil Plants of Western North America*, by William Tidwell (1975), is a fine treatment of the subject. It is aimed at the amateur but is widely found on professional paleobotanists' bookshelves as well. It has 197 pages of illustrations, descriptions, and discussions of fossil plants and may be purchased at university bookstores, museum giftshops, and bookstores in general.

Professional paleontologists are usually willing to help the serious amateur in identification, provided the collector does not overload these busy and highly trained people. Partly this is because many of them are generous souls and partly because this sharing is a two-way street. Amateur collectors sometimes make significant finds that are a tremendous help to professionals.

PHOTOGRAPHING

Among the reasons for keeping a photographic file of selected fossils in your collection are the following: (1) Folios of photographs are compact. It is quicker to refer to a well-organized photo file than bulky trays of specimens. (2) Photos are useful for publication and lecture. (3) A certain number of your specimens will inevitably be lost because they may deteriorate or break, they may be misplaced, some may be borrowed and never returned, or some may be given to a colleague. A good photograph, however, keeps the needed data available.

Presently, publishers of scientific papers seldom print color photographs. Black-and-white glossy photographs with the best possible contrast and detail and including an object (often part of a metric ruler) for scale are used. Color slides are fine for lecturing. Two floodlights (250 to 500 watts each) aimed at the subject from opposite sides at low angles provide effective lighting. A slow shutter speed combined with a small aperture opening and the use of slow film (low ASA number) help to get maximum detail. For publication, where possible, showing the specimen at natural size is desirable. Microscopic specimens, of course, need enlargement, and very large specimens must be reduced in size. You should use a tripod or camera stand to avoid blurring of the image due to vibration.

SHARING YOUR INFORMATION

No matter what your collection holds, it will not advance the field of paleontology until its contents are known by other students of the past. Some collectors give talks to schools and civic groups. Many eventually donate significant finds or entire collections to museums. Another worthwhile method of disseminating information on what you have found is through publication. Many serious collectors have published papers in scientific publications, and by doing so have made contact with specialists who have been able to use information from their collections and in turn have helped with identification.

WHAT WILL EVENTUALLY HAPPEN TO YOUR COLLECTION?

If you do not dispose of your collection while you are alive, it will be done later by someone else. No one knows as well as you do where the specimens will be best used. Don't wait too long. I have been made uncomfortable at times by seeing good collections left to the care of heirs who allow them to languish, become scattered, and eventually be lost. Some heirs do not place a great deal of significance on the collections and allow them to be removed piecemeal as curiosities. Some have ended as playthings of children.

WHAT IS THE MONETARY VALUE OF YOUR COLLECTION?

The main value of a collection is in the information it provides. Its actual value on the market is highly overrated by most laymen. Lifetime collections of large size and significant finds have sold for less than the actual out-of-pocket expenses involved in collecting them. If the collector's time were added into the collecting cost, probably no sale of collections would show a break-even figure.

Because of these facts and the public's general misconception of fossil dollar values, museum curators are often put in the uncomfortable position of being asked to appraise the value of a collection and then finding themselves maligned for supposedly trying to undervalue the items so they can get the collection cheaply.

LAWFUL COLLECTING

Collecting of fossils on public lands may be restricted by the local or regional administrator of the supervising agency. No collecting is permitted in national parks except by qualified institutional groups or their representatives. In USDA Forest Service (USFS) or U.S. Bureau of Land Management (BLM) areas, permission to collect is usually granted if the specimens collected are to be used for hobby or scientific purposes.

How much collecting should be allowed on federally owned lands has long been an unsettled issue. The balancing of five different needs is a thorny problem. Those needs are (1) the need to protect scientifically important or rare specimens from perpetual loss; (2) the need to protect fossil deposits from massive overcollecting by commercial collectors; (3) the need of scientific researchers to have access to fossils; (4) the need of the tax-paying public for recreational or hobby collecting of limited numbers of fossils; and (5) the need to avoid destruction of fossils by weathering. Despite years of conference within and between federal agencies, the issue remains unsettled and is mostly dealt with by individual land managers.

*(Continued on page 94, **Fossils**)*

Thunderegg collecting in Oregon

by Paul F. Lawson, mineral collector and retired Supervisor, Mined Land Reclamation Program, Oregon Department of Geology and Mineral Industries

HISTORY

The Thunderegg was designated Oregon's official state rock by the Oregon Legislature in 1965. Its selection was supported by a 2 to 1 vote by members of the mineral and gem clubs of Oregon and by the patrons of the Oregon Museum of Science and Industry (OMSI).

The Thunderegg has long been important to Oregonians. According to ancient Indian legend, when the Thunder Spirits living in the highest recesses of snowcapped Mount Hood and Mount Jefferson became angry with one another, amid violent thunder and lightning storms they would hurl masses of these spherical rocks at each other. The hostile gods obtained these weapons by robbing the nests of the Thunderbirds of their eggs, thus the source of the name "Thundereggs." The mountains are still key landmarks in the beautiful High Cascade Range, and millions of Thundereggs are on the lower lands as evidence of the legend and for all to enjoy.

The Thunderegg has been highly prized by collectors, lapidarists, jewelry makers, and interior decorators for nearly 100 years. In 1893, Dr. George F. Kunz, Tiffany's famed gem authority, estimated that as much as $20,000 worth of opal-filled eggs from one Oregon deposit had been marketed in 1892. Since the mid-1930's, thousands of visitors from every state in the Union and many overseas countries have come to Oregon to hunt Thundereggs. Many Oregonians have also joined them.

Thundereggs are made into beautiful jewelry, especially bolo ties and pendants, pen stands, bookends, and decorator pieces. Their value ranges from about $1 per slice or half egg to well over $100 per slice or single cabochon. Thundereggs and their products can be purchased through magazine ads; at gem or rock shows; from tailgaters at outdoor events; at gem or lapidary shops; and at airport, motel, hotel, and restaurant gift shops or counters.

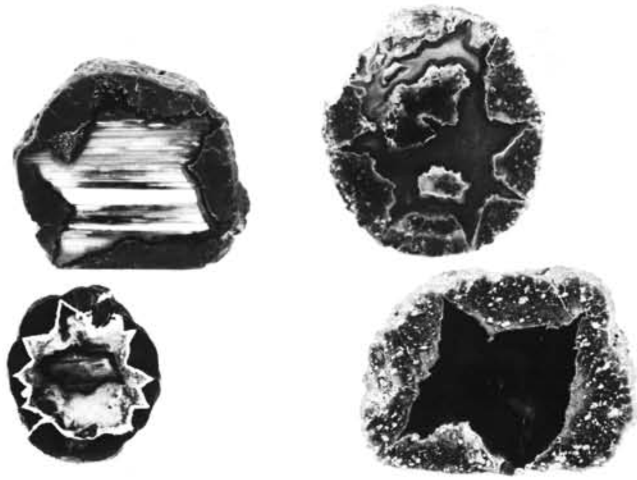
HOW THUNDEREGGS FORM

Although the Thunderegg is an honorary rock by Legislative decree, it actually is not a rock. It is a structure, sometimes a nodule, sometimes a geode, occurring in rhyolite, welded tuff, or perlitic rocks. However, without question, the Thunderegg is by far the most popular "rock" in Oregon.

Scientists do not agree on the processes forming Thundereggs. Some insist that the characteristic and unique internal pattern of typical Thundereggs is due to expansion and rupture of rock by gases. Others claim the pattern is due to desiccation (drying) of a colloid or gel. Whatever the process, however, after the cavity that contains the egg is formed, further development is extremely variable in the amount of time needed to complete the egg, in the degree and type of infilling, and in other physical characteristics. Thundereggs range in size and weight from less than an inch and under 1 ounce to over a yard in diameter and over a ton in weight. Most eggs collected are between 2 and 6 inches in diameter.

Digging for thundereggs in the Blue Beds at Richardson's Recreational Ranch. Photo courtesy of Lewis Birdsall.

Outside appearance of Thundereggs from different localities in Oregon: Madras-Prineville area (upper and lower left), southeastern Oregon area (upper right), Burns area (lower middle), and Lakeview area (lower right).



Typical inside appearance of Thundereggs that were cut and polished.

HOW THUNDEREGGS LOOK

Typically, an egg has a russet-colored outer shell that is often knobby and often has a characteristic ribbed pattern. Frequently, the inside of the outer shell has a relatively thin intermediate or transitional lining. This is sometimes composed of an iron or manganese compound, often with a thin coating of opal or chalcedony. Sometimes only opal or chalcedony is apparent. Finally, the center of an egg is usually filled with chalcedony or opal and may or may not have inclusions, pattern growth, or crystals. In some variants, the egg may be hollow or may have a thin layer of chalcedony coating the interior. This layer sometimes is topped with a coating of small quartz crystals.

Growths of algaelike tubes, or plumes, or "moss" of manganese or iron compounds or of clay may be free standing or partially or wholly embedded in chalcedony. Some eggs with plumes ("flowers") in chalcedony are among the most valuable specimens. Several zeolites have been observed or reported in Thundereggs; clinoptilolite is fairly common, and mordenite, natrolite, and mesolite have also been reported.

Thundereggs are sometimes found with fortification banding just inside the shell, then an area of horizontal layering, with the remaining central area filled with clear chalcedony or inward-pointing quartz crystals. Banding and layering vary in color, thickness, and content. Some layers are composed of a fibrous cristobalite (lussatite). Other eggs have a partial botryoidal filling of an opal form of low cristobalite. This opal is often fluorescent because of a low content of uranium salts.

One collecting site in Oregon has eggs filled with carnelian. At another, the filling may contain cinnabar, which colors it pastel to intense red. Some eggs are filled with pastel jaspers. Others may have any one of a variety of opal fillings that may be opaque blue, opaque red, translucent pastel blue, translucent yellow, translucent red, white, or colorless. Some of the opal can be faceted, and a small percentage is true precious opal.

Some eggs have well-developed calcite crystals encased in chalcedony, and others contain pseudomorphs of chalcedony after calcite. Some eggs have layering that is fanned from one edge, because the egg was rotated by earth movement while the filling was being deposited. This and other features suggest that the complete development of some eggs may have taken considerable time, and the filling-in of the egg may have recorded a series of geologic events. Some eggs contain brecciated rock fragments, while others show faulting, offset, and healing. One of the most unusual Thunderegg variants is up to 3 feet long and 2 to 3 inches in diameter and looks much like a fat gray worm. In some areas, it is common to find the characteristic chalcedony core weathered out of its shell.

If a complete egg is sawed in the right orientation, one or more conduits through which filling materials flowed may be found. The beauty and complexities of many of the cut and polished eggs explain why Oregon rockhounds have long been fascinated by Thundereggs.

WHERE TO FIND THUNDEREGGS IN OREGON

Thundereggs can be collected at many sites in Oregon. Some localities occur in beautiful forested hill country, others in dry, desertlike terrain. It should be understood that Thundereggs have been eagerly collected in Oregon for fifty years. Therefore, on "free sites," collectors must expect to dig and work for Thundereggs. Proper equipment, including shovel, pick, and bar, makes the job much easier. The "fee" site will almost always have some preparatory work (overburden removal) done. Also, eggs may usually be purchased at the site office. Some places may have tools for rent.

LOCATIONS

Madras-Prineville area

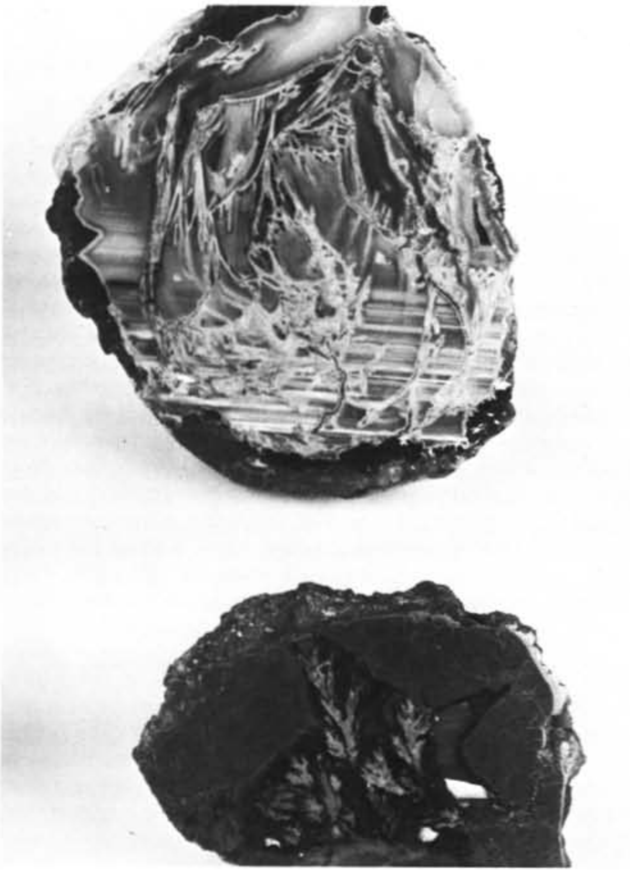
White Fir Spring (National Forest land; free site)
Whistler Spring (National Forest land; free site)

For current information on these sites, contact
Prineville Ranger District
2321 East Third
Prineville, OR 97754
(503) 447-3825

White Rock (or Wildcat Mountain) (National Forest land; free site)

For current information on this site, contact
Big Summit Ranger District
348855 Ochoco Ranger Station
Prineville, OR 97754
(503) 447-3845

A map of the area's free collecting sites (including sites for other rockhound materials) is available from
Prineville Chamber of Commerce
390 North Fairview
Prineville, OR 97754
(503) 447-6304.



Rarer formations in Thundereggs from the Priday beds (Madras-Prineville area): Green moss agate (top) and red, yellow, and orange plume agate (bottom).

Current information is also available from
H.L. Elkins Gemstones
833 South Main
Prineville, OR 97754
(503) 447-5547
and from the following private (fee) sites:

Richardson's Recreational Ranch (fee site)
Gateway Route, Box 440
Madras, OR 97741
(503) 475-2680
(Combines old Priday and Kennedy Ranch beds. Also includes a variety of agate and jasper materials.)

Hay Creek Ranch (fee site)
Ashwood Star Route
Madras, OR 97741
(503) 475-7237
(Several egg beds and also other varieties of agate and jasper materials are available.)

Lucky Strike Thundereggs (fee site)
P.O. Box 128
Mitchell, OR 97750
(503) 462-3176

Lakeview area

Crane Creek (free site)

Thunderegg from central Oregon showing a fracturing event during which jaspery breccia entered the Thunderegg. Photo courtesy John E. Allen, Emeritus Professor, Department of Geology, Portland State University.

For current information on this site, contact
High Desert Craft Rock Shop
244 North M
Lakeview, OR 97630
(503) 947-3237

Burns area

Buchanan (fee site)
For current information on this site, contact
Highland Rock and Gift Shop
1316 Hines Boulevard
Burns, OR 97720
(503) 573-2995

Southeastern Oregon area

Succor Creek (free site)
For current information on this site, contact
Emil Wohlcke
Chairman, Thunderegg Days
707 Emison Avenue
Nyssa, OR 97913
(503) 372-3715
or
Bureau of Land Management
100 Oregon Street
Vale, OR 97918
(503) 473-3144

GOOD HUNTING! □

Current assessment of earthquake hazard in Oregon

by Robert S. Yeats, Department of Geology, Oregon State University, Corvallis, Oregon 97331

Five years ago, very few people were concerned about major earthquakes in the state of Oregon. Historical damaging earthquakes had been recorded in the adjacent states of Washington, Idaho, Nevada, and California, but not Oregon. This lack of concern is expressed today in seismic zoning maps, which put the state of Oregon in a lower seismic risk category than adjacent states.

Today, the earth science community appears to have reached a consensus that Oregon has been struck by large earthquakes in the past and therefore that Oregon is likely to be subjected to large earthquakes in the future. There is no agreement among earth scientists on whether Oregon will be subjected to a magnitude 9 or only a magnitude 7 earthquake. Nor is there compelling evidence for past large earthquakes directly beneath the heavily populated Willamette Valley. But the evidence found in marshes in estuaries on the Oregon coast is compelling enough for reevaluation of seismic zoning maps and of the seismic safety of critical facilities such as power plants, hospitals, and dams.

In evaluating earthquake hazards, it is not enough to show that crustal deformation has taken place in the recent past, because such deformation could take place slowly and smoothly, unaccompanied by earthquakes. It is necessary to show that deformation occurred in sudden jerks, as it does during an earthquake.

In Oregon and Washington, scientists have now shown that coastal marshes and coniferous forests have recently undergone sudden subsidence that killed the marshes and forests by inundating them with sea water. Sand commonly found overlying the marshland sediments shows strong evidence of having been deposited by a seismic sea wave, or tsunami. Sand of this kind has been reported from the Salmon River and Alsea Bay, Oregon, and from Willapa Bay, Washington.

Many attempts have been made to account for the buried marshes by nonseismic processes, notably gigantic, 500-year storms or a slow rise in sea level. Sea-level change in the last 5,000 years does not appear to be large enough to account for the marshland burials. Marshes on the East Coast and Gulf Coast of the United States have been subjected to great storms in the past, notably hurricanes, but these marshes do not show evidence of rapid burial. However, marshes around the Gulf of Alaska and in southern Chile do show evidence of rapid burial, including burial after the 1960 Chile earthquake (magnitude 9.5) and the 1964 Alaska earthquake (magnitude 9.2). We cannot completely exclude the possibility that the marshes could have been mantled with sand by a gigantic Pacific storm occurring during a time of temporary sea-level rise in the last few thousand years. But this explanation has very little support among scientists because it is unlikely that a great storm and a temporary sea-level rise would have coincided seven or eight times in the last 5,000 years.

The only note of caution about correlating marsh subsidence with earthquakes is the absence of evidence of strong shaking of marsh deposits that would be expected during a great earthquake.

The most recent great coastal subsidence event occurred 300 to 400 years ago, as dated by carbon-14, and is known to have inundated many marshes and forests from Grays Harbor in Washington to Alsea Bay in Oregon. Carbon-14 dates from partially submerged archeological sites are consistent with submergence during the most recent event as well as an earlier event 3,100 years ago. However, carbon-14 dates do not permit us to say whether a given subsidence event occurred in one earthquake or in several over a period of 50 years. We could calculate the magnitude of an earthquake rupturing the subduction zone from Grays Harbor to Alsea Bay, but this would be considered as a maximum possible event. Tree-ring dating could increase the time resolution, but only where the subsidence events are recorded by killed trees in lowland forests.

These probable subduction-zone earthquakes have occurred on average every 500 to 600 years, but there is so much variation in recurrence interval over the past 4,000 years that the average recurrence interval has little value in predicting the next earthquake.

Sediment cores from the abyssal sea floor at the foot of the continental slope west of Oregon provide evidence of strong shaking, perhaps related to the abrupt coastal subsidence. Sediments deposited on the continental shelf by major rivers, particularly the Columbia River, were apparently destabilized and sent down the continental slope as a high-density, sediment-charged flow analogous to a snow avalanche, but much larger. The most likely triggering mechanism was a giant earthquake. The cores also recovered deposits of ash from the Mount Mazama eruption that formed Crater Lake about 7,600 calendar years ago. Based on the number of turbidity-current deposits on top of the Mount Mazama ash, the average interval between successive turbidity-current deposits is about 500 to 600 years, with the most recent deposit about 300 years ago. These estimates resemble those for marshland subsidence events, adding support for the origin of both by great earthquakes.

Accurate repeated leveling surveys of Oregon highways provide evidence for deformation in the last 100 years. This releveling study is in its early stages, because the highways were last releveled in 1987, and the data are only partially analyzed. However, there is clear evidence of eastward tilting of the Coast Range toward the Willamette Valley, northward tilting of the coast between southern Oregon and Newport, and southward tilting of the coast between Astoria and Tillamook. We cannot say whether this deformation represents elastic strain accumulation prior to a future earthquake or whether this deformation has nothing to do with earthquakes. This is a profitable line of investigation, however, and future studies may lead to more definitive evidence from geodetic evidence of this kind.

Studies in the Willamette Valley have not yet produced evidence that the Portland Hills fault, Gales Creek fault, Corvallis fault, and other faults in the Valley are active and capable of producing earthquakes. In addition to these faults, there are broad folds in the Tualatin Valley and Portland basin. The faults are not long and throughgoing, as they are in California, but instead are relatively short and offset at right angles by other faults. The faults and folds are consistent with the observed stress field of western Oregon, which is characterized by the maximum compressive stress oriented north-south. These faults and folds clearly deform flows of the Columbia River Basalt Group deposited 16.5 to 12 million years ago. Most of these structures also deform semiconsolidated sediments that overlie Columbia River basalt, but these sediments are poorly dated. If these sediments are as young as a few hundred thousand years, then these faults would be shown to be capable of generating future earthquakes. Investigations to answer these questions are underway.

The only clear evidence for recent crustal earthquakes comes from the South Slough of Coos Bay, where marshes show evidence of at least eight burial events in the last 5,000 years. South Slough is in the axis of a syncline, or down-fold, and the buried marshes show that this syncline was formed by a series of earthquakes, possibly on a deeply buried fault that nowhere reaches the surface. Coos Bay is at the eastern margin of a zone of active faults and folds that extends north-northwestward offshore, parallel to the foot of the continental slope and not parallel to the coastline, which extends northward. These faults and folds respond to the northeastward subduction of the Juan de Fuca Plate beneath Oregon and are not in accord with the north-south principal compressive stresses measured elsewhere in western Oregon. Thus, we cannot apply the evidence for earthquakes at Coos Bay directly to the Willamette Valley, which is much farther inland from the trench.

Western Oregon has very few instrumentally recorded earthquakes, and most of these are in the Portland area, part of a zone that extends northward into Washington. Part of the reason for so few earthquakes is that Oregon has very few seismographs to record small earthquakes, as compared with adjacent states. For this reason, small earthquakes that could be recorded in Washington or California are not recorded in Oregon. However, the lack of larger earthquakes, magnitude greater than 2.5, is not an artifact of poor instrumentation. The Washington network has recorded many earthquakes in the North American crust and many more in the deep oceanic slab that is now being subducted, but none on the interface between the two plates, the place where subduction-zone earthquakes would occur. The absence of earthquakes could be explained by very smooth, frictionless subduction or by subduction having stopped entirely. Neither explanation is likely. The most logical explanation is that the subduction zone is completely locked and is building up strain for a future earthquake. Most of the San Andreas fault that ruptured in great earthquakes in 1857 and 1906 is seismically quiet, like the Willamette Valley. The Coos Bay region, with the only clear evidence for recent crustal earthquakes, is also seismically quiet. Even so, the compete absence of instrumentally recorded earthquakes on the subduction-zone interface is difficult to explain.

The lack of historical earthquakes should not be taken as evidence for low seismic hazard, because Oregon's recorded history spans less than 200 years, which is not sufficient time to be significant in earthquake-hazard evaluation. The submergence of archeological sites indicates that earthquakes affected Native American communities prior to the establishment of a culture that kept written records. The Armenian earthquake of December 1988 occurred in an area that had not had a major earthquake in 700 years, based on historical records. A large portion of that part of the San Andreas fault of California that ruptured in great earthquakes in 1857 and 1906 is now as seismically quiet as the Willamette Valley. The southern San Andreas fault has not had a major earthquake in several hundred years, and a long-range prediction experiment is now underway in that region.

In conclusion, the marsh evidence is convincing enough to issue a public warning about earthquake hazard in Oregon. We cannot say how large a subduction-zone earthquake could be, nor can we forecast when the next one might occur. We also have not been able to assess the earthquake hazard posed by local earthquake sources beneath the Willamette Valley. We are on the steep part of the learning curve, and there are many challenges ahead of us. □

The 15 most significant earthquakes in U.S. history

For National Earthquake Awareness Week, April 2-8, 1989, the U.S. Geological Survey (USGS) released a list of the 15 most significant earthquakes in the history of the United States.

Robert Wesson, chief of the Office of Earthquakes, Volcanoes, and Engineering at the USGS National Center in Reston, Virginia, said the basis for selection of the 15 earthquakes is a combination of magnitude, damage, and casualties.

Earthquakes are measured in two basic ways: magnitude and intensity. Magnitude is an instrumental measure of the amount of energy released by an earthquake, as indicated by ground motion. Magnitude scales theoretically have no upper limit. The Modified Mercalli Scale (MMS) of intensity, using Roman numerals, is based on human judgment of the amount of damage and effects caused by earthquakes and ranges from I (not felt) to XII (almost total destruction of human-made structures).

The 15-most significant earthquakes in U.S. history, listed in order of the time of their occurrence, are as follows:

1. Cape Ann, Massachusetts, November 18, 1755. Estimated magnitude 6.0, maximum MMS intensity VIII. It was centered in the Atlantic 200 mi east of Cape Ann and was felt over 400,000 mi^2, from Nova Scotia south to Chesapeake Bay and from Lake George, N.Y., east into the Atlantic. Damage was heaviest on Cape Ann and in Boston, with about 100 chimneys destroyed.

2. New Madrid, Missouri, seismic zone, 1811-1812. In the most violent series of earthquakes in U.S. history, three earthquakes (in this list counted as one) hit the New Madrid seismic zone in southeastern Missouri and northeastern Arkansas on December 16, 1811, and January 23 and February 7, 1812, at estimated magnitudes of 8.4 to 8.7 and maximum MMS intensities of XI. Damage and casualties were not great because the area was sparsely populated, but the earthquakes were felt over the entire United States east of the Mississippi River and probably far to the west. The earthquakes caused extensive changes in the surface of the land.

3. Virgin Islands, November 18, 1867. Estimated magnitude 7.5, maximum MMS intensity VIII. It was felt from the Dominican Republic to the Leeward Islands. Property damage occurred in the Virgin Islands and Puerto Rico, some caused by 20-ft sea waves triggered by the earthquake.

4. Charleston, South Carolina, August 31, 1886. Estimated magnitude 6.6, maximum MMS intensity X. It killed 60 people. Most buildings in the Charleston area were damaged or destroyed, with losses of $20 million. It was felt in New York City, Boston, Milwaukee, Havana, and Ontario.

5. Charleston, Missouri, October 31, 1895. Estimated magnitude 6.2, maximum MMS intensity IX. It was near the junction of the Mississippi and Ohio Rivers and was the strongest shock in the New Madrid seismic zone since the three great earthquakes in 1811-1812. It was felt over 1 million square miles in 23 states and Canada, caused considerable damage, and created a four-acre lake near Charleston.

6. San Francisco, California, April 18, 1906. Estimated magnitude 8.3, maximum MMS intensity XI. Although known as the San Francisco earthquake, the 1906 shock actually ruptured the San Andreas fault along a 270-mi-long segment from San Benito County north to Humboldt County. Fault slip was up to 21 ft in Marin County. Damage was estimated at more than $24 million, directly from the earthquake and from the fires that followed in San Francisco. The death toll from the earthquake and fires was more than 700 persons.

7. Mona Passage, Puerto Rico, October 11, 1918. Estimated magnitude 7.5, maximum MMS intensity IX. It was one of the most violent recorded on Puerto Rico and was followed by a tsunami that drowned many people. The death toll was 116, and damage was estimated at $4 million.

8. Long Beach, California, March 10, 1933. Although the magnitude was only 6.2, and the maximum MMS intensity was VIII, this earthquake was one of the most destructive in the United States because it was in a heavily settled area, with many poorly constructed buildings, including schools. About 115 people were killed, and hundreds more were injured. Damage was estimated at $40 million. The earthquake led to stricter construction codes in California to mitigate earthquake damage.

9. Olympia, Washington, April 13, 1949. Magnitude 7.1, maximum MMS intensity VIII. This earthquake caused heavy damage in Washington and Oregon. Eight people were killed, and many others were injured. The earthquake was felt eastward to western Montana and south to Cape Blanco, Oregon.

*(Continued on page 92, **Earthquakes**)*

MINERAL EXPLORATION ACTIVITY

Introduction

This is the first of a new series of columns that will appear in each issue of *Oregon Geology*. Entitled "Mineral Exploration Activity," the column will provide up-to-date information to the public and the mineral industry about current mineral exploration activities in Oregon.

In each column, a table will list the names of exploration sites until they are reclaimed and abandoned or until they start production. Public meetings regarding specific mining projects will also be announced.

Readers who have questions or comments about this new listing should contact Gary Lynch or Allen Throop in the Albany office of the Oregon Department of Geology and Mineral Industries (DOGAMI), phone (503) 967-2039.

Public hearing

An informational meeting to discuss the Atlas Precious Metals Grassy Mountain project and the roles of the Bureau of Land Management (BLM), DOGAMI, the Department of Environmental Quality, and Malheur County took place on July 6, 1989, in Vale. For details about what happened at the meeting, contact Allen Throop of DOGAMI (see above phone number) or Ralph Heft of the Vale BLM office, phone (503) 473-3144.

Major metal mining 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
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	App
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	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. □

(Earthquakes, continued from page 91)

10. Hebgen Lake, Montana, August 17, 1959. Magnitude 7.3, maximum MMS intensity X. The strongest recorded earthquake in Montana was felt over 600,000 mi², from Seattle, Washington, to Banff, Alberta, Canada, to Dickinson, North Dakota, to Provo, Utah. It caused massive waves on Hebgen Lake that did not subside for 12 hours and also caused a large landslide that blocked the Madison River canyon, creating a large lake. At least 28 people were killed, and damage was extensive to summer homes and highways in the region.

11. Prince William Sound, Alaska, March 27, 1964. This magnitude-8.4 Good Friday earthquake is the second strongest in the world during the 20th century, topped only by a magnitude-8.6 earthquake in Chile in 1960. The maximum MMS intensity was X. The Alaska earthquake triggered extensive landsliding and generated tsunamis. It caused an estimated $311 million in damage in Anchorage and south-central Alaska and killed 131 people. As a result of this earthquake and a magnitude-6.5 tremor in the San Fernando Valley of California in 1971, the federal government, mostly through the USGS, greatly expanded its research on earthquakes.

12. Seattle, Washington, April 29, 1965. Magnitude 6.5, maximum MMS intensity VIII. This second strongest recorded earthquake in Washington was felt over 130,000 mi² of Washington, Oregon, Idaho, Montana, and British Columbia. Seven people were killed, and damage was estimated at $12.5 million.

13. San Fernando, California, February 9, 1971. Magnitude 6.6, maximum MMS intensity XI. It killed 65 people, injured many others, and caused $1 billion in damage in the Los Angeles area. As a result of this earthquake and the 1964 Good Friday earthquake in Alaska, the federal government greatly expanded its earthquake research and re-evaluated seismic design for hospitals and other critical facilities.

14. Coalinga, California, May 2, 1983. Magnitude 6.7, maximum MMS intensity VIII. It injured 45 people and caused $31 million in damage, with the worst damage occurring in downtown Coalinga. The earthquake was felt from Los Angeles to Sacramento and from San Francisco to Reno.

15. Borah Peak, Idaho, October 25, 1983. Magnitude 7.0, maximum MMS intensity IX. The largest earthquake recorded in Idaho was felt over 330,000 mi². Two children were killed in Challis, Idaho, and damage was estimated at $12.5 million.

—*USGS news release*

Gunnar Bodvarsson dies

Gunnar Bodvarsson, Professor Emeritus of mathematics and geophysics at Oregon State University (OSU), died in Corvallis in May 1989. A member of the OSU College of Oceanography faculty, he specialized in geophysical oceanography. His interests and research projects were far reaching and ranged from fisheries to geothermal and nuclear energy problems.

Born 1916 in Reykjavik, Iceland, Bodvarsson received an engineering degree in Munich, Germany; a mathematics and engineering degree in Berlin; and a doctorate from the California Institute of Technology in Pasadena. He worked as an engineer in Copenhagen and later served as chief engineer with the State Drilling Authority of Iceland and the Geothermal Department of the State Electrical Authority of Iceland. In 1964, he joined the faculty of OSU, where he remained until his retirement in 1984.

Bodvarsson worked as a consultant for the United Nations in several countries in South America, including Mexico, Costa Rica, El Salvador, Guatemala, Nicaragua, and Chile.

Among his honors and awards were the Oregon Academy of Science Award for 1979, the Geothermal Pioneer Award from the Geothermal Resource Council in 1988, and an honorary doctorate from the University of Iceland in 1988.

His survivors include his wife Tove, three children, and one grandson. □

Glenbrook Nickel facility in Riddle starts production

Cominco Resources International, Ltd., has announced that its wholly owned U.S. subsidiary, Cominco American Resources, Inc., has rehabilitated and is operating the former Hanna Nickel Smelting Company plant near Riddle, Oregon, through Glenbrook Nickel Resources, a joint venture of Cominco American and USA Investments, an investment and reality company based in Bozeman, Montana.

M.A. Hanna Company of Cleveland permanently closed the mine and smelter in January 1987, when nickel prices fell to below $2 per pound. Nickel Mountain Resources, a subsidiary of Universal Consolidated Companies of Fremont, Ohio, purchased the assets of the mine and smelter from Hanna in October 1987 and currently has a lease-purchase arrangement with Glenbrook Nickel Resources.

The companies have been evaluating the possibilities of processing a stockpile of 6 million tons of lateritic nickel ore, grading at 0.7 percent nickel, that was left at the site by Hanna when the drop in nickel prices made it too expensive to process. However, the recovery in nickel prices to as high as $10.80 a pound in March 1988 and to an average price ranging between $5 and $6 a pound in June 1988 has made it feasible to process the stockpile. Glenbrook's plans include starting production of ferrosilicon in June, followed by ferronickel in July.

Glenbrook hired about 80 people to rehabilitate the smelter complex and eventually plans to employ about 250 people at the plant. □

AGI/GIS offer new edition of guidebook list

A new, the fifth, edition of the *Union List of Geologic Field Trip Guidebooks of North America* has been compiled and edited by the Guidebooks Committee of the Geoscience Information Society, Charlotte Derksen, Chair, and published by the American Geological Institute (AGI). The more than 6,500 field-trip guidebooks listed in this 223-page volume were written for field trips held between 1891 and the end of 1985. The *Union List* is now available for the price of $60 from Customer Service, AGI, 4220 King Street, Alexandria, VA 22302. Credit-card orders may be placed by phone to (800) 336-4764.

The main part of the *Union List* is arranged by organizations that hold meetings or conferences. Under each organization, its meetings and the guidebooks issued at these meetings are arranged chronologically.

The individual field-trip guide citation includes information about which libraries have copies and what the lending policies of those libraries are. More than 200 libraries in Canada and the United States have contributed to this edition.

The main part of the list is followed by a geographic index and, for the first time in the publication history of the *Union List*, a stratigraphic index.

It is often difficult to obtain guidebooks for the field trips held at geology meetings every year. Few are available for purchase after the field trips have taken place. Many field-trip guidebooks are not announced in publishers' lists, even though such guidebooks can be significant sources of local geology information. Sometimes interlibrary borrowing of a guidebook may be the only way for someone to obtain a copy. The Union List is intended to alleviate this situation, both as a bibliography and as a finding tool. □

Changes in DOGAMI publication sales announced

The publication sales section of the Oregon Department of Geology and Mineral Industries (DOGAMI) has announced some changes in its publication sales.

Available publications

The *Geologic map of Oregon east of the 121st meridian*, Map I-902 published by the U.S. Geological Survey (USGS), is now out of print and will not be reprinted. A new, single-sheet geologic map for the entire state is currently in preparation and expected to become available in 1990. In the meantime, DOGAMI will offer blackline copies of Map I-902 along with photocopies of the legend.

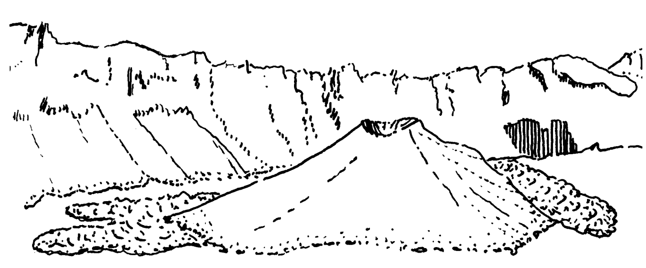
DOGAMI now carries the available maps of the USGS series of 1:100,000-scale (30- by 60-minute) topographic maps, which sell for $4 and have turned out to be quite popular. Maps for about half the state are available now, and DOGAMI will add the new ones as they are issued.

The USGS 1:1,000,000-scale base map for the entire state is also newly offered ($4).

The special packets on minerals and counties are currently being reorganized and updated and will not be available for a while.

Ordering convenience

Orders for publications will now be accepted via mail, phone or Fax (503-229-5639), if they are charged to Mastercard or Visa. No minimum amount of the order is required for this service, but a 10-percent handling fee will be charged for orders taken over the phone. As before, orders are still mailed with no additional charge for postage. □



Position Announcement
Oregon Department of Geology and Mineral Industries

Marine minerals coordinator

Full-time permanent position, available October 1, 1989. Starting salary approximately $2,200-$2,500 per month plus generous fringe. Location is Portland, Oregon.

Graduate degree and marine minerals experience are required, as well as a minimum of four years of progressively responsible experience in acquisition, evaluation, interpretation, and management of marine technical and/or economic data. The successful candidate will provide marine mineral resource input to a multidisciplinary offshore State planning effort for the Oregon coast and offshore area.

Duties will include management of the Department's marine minerals program, negotiating and administering contracts for offshore studies, planning and conducting meetings and symposia, writing and presenting clear and concise reports and publications, and participating in the geologic aspects of coastal land use planning and offshore resource planning. This position also requires effective communication with a diverse public, providing the public service role for the Department on offshore issues and serving on offshore planning committees. Close coordination with the public; local government; and Federal, State, university, and industry counterparts is required.

Interested applicants should send resumes and three references, including name and phone number, from present and previous supervisors, as well as requests for the necessary application packet to the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, Oregon 97201-5528, phone (503) 229-5580. Deadline for receipt of completed application packet is September 1, 1989.

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***(Fossils**, continued from page 86)*

A spokesman for the Portland, Oregon, BLM office stated, "There is a prohibition against collecting vertebrate fossils except for scientific purposes. A permit is required from the surface management agency. On BLM lands, there is a limit of 25 pounds plus one piece per day for petrified wood collection, with an annual limit of 250 pounds per person. Collection of small, noncommercial quantities of hobby materials is allowed free of charge. Gathering or collecting for the purpose of sale or barter is prohibited unless especially authorized. Collection on recorded mining claims is not advised without the mining claimant's consent because of legal problems that might arise between the claimant and the collector."

USFS regulations prohibit excavating, damaging, or removing any vertebrate fossil or removing any paleontological resource for commercial purposes without a special-use permit.

If you have any questions about whether you may collect at a specific site, be sure you contact the local office of the appropriate federal agency if you are on federal land, the appropriate state agency if you are on state land, and the property owner if you are on private property.

LAY DOWN THE MAGAZINE, GRAB YOUR ROCK HAMMER, AND GO!

If you know of a spot where fossils are found and may be collected, you are ready to start. If not, hit the nearest library to get a clue, and then make a try. You are sure to enjoy your experience. As with other adventures, getting off and running may be a bit confusing, but remember, "The longest of journeys begins with but one step." Have fun. Before long, you will be looking for room to house your collection and will be proudly showing it to the public. Just be sure none of your finds ends up as a clock on a study wall for lack of identification marking.

ACKNOWLEDGMENTS

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REFERENCES CITED

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Steere, M.L., 1977, Fossils in Oregon: A collection of reprints from the Ore Bin: Oregon Department of Geology and Mineral Industries Bulletin 92, 227 p.

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ABSTRACT

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

GEOLOGIC, STRUCTURAL, AND GEOCHEMICAL FEATURES OF BASALTIC AND RHYOLITIC VOLCANIC ROCKS OF THE SMITH ROCK/GRAY BUTTE AREA, CENTRAL OREGON, by Walter A. Obermiller (M.S., University of Oregon, 1987), 189 p.

Rocks of the Smith Rock/Gray Butte area reflect Tertiary bimodal volcanic activity in central Oregon. Ages of the units, formerly thought to be Eocene-Oligocene, were estimated by means of leaf fossils and new K-Ar ages obtained in this study and were found to span the range of approximately 36 to 10 m.y. The Smith Rock tuff and the Gray Butte rhyolite were determined to be Miocene in age. Abundances of major, minor, and trace elements were determined for basalts and rhyolitic rocks of the study.

Basaltic rocks, which include subordinate olivine-phyric tholeiites and aphyric basaltic andesites, feature large TiO_2 abundances, as they are characteristic for extensional environments. The most important petrogenetic process for the basalts is fractional crystallization. Mass-balance calculations in conjunction with trace-element models confirm this model.

Rhyolites and ash-flow tuffs exhibit typical recrystallization textures, and their major-element compositional features are believed to have changed. They are mostly corundum normative. Other notable features of the rhyolites include negative Eu anomalies and large Ni and Hf abundances similar to those in Icelandic rhyolites. Nd- and Pb-isotope ratios suggest crustal involvement in the petrogenesis of both basalts and rhyolites. Crystal fractionation models to derive rhyolites from contemporaneous basaltic andesites fail to produce the enrichment of trace elements observed in the rhyolites. Trace-element models involving partial melting (approximately 14 percent) of basaltic andesite to produce rhyolites are capable of explaining the observed trace-element enrichments but cannot be supported by a major-element model, because the compositions of feldspars are expected to change unpredictably during partial melting. □

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