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COVER PHOTO:
South Falls, Silver Falls State Park. See article beginning on page 3. (Photo courtesy Oregon State Highway Division)

CONTENTS

To our readers:

This issue of OREGON GEOLOGY introduces the fourth format for the Department of Geology and Mineral Industries' monthly publication. Changes began 40 years ago, when THE ORE BIN replaced the PRESS BULLETIN. Then, in 1962, the mimeographed ORE BIN became the popular printed version.

The magazine's readership has grown. Well more than one-third of the copies mailed in the U.S.A. go outside Oregon. In addition, some of today's subscribers live in Canada, England, France, Germany, Japan, New Zealand, and South Africa.

OREGON GEOLOGY will be found, as has been THE ORE BIN, in school libraries just about anywhere - - on the desks in executive suites, on shelves in private consultants' offices, and on coffee tables in hundreds of homes.

As it became more and more widely read, THE ORE BIN became broader in content. OREGON GEOLOGY will continue this metamorphosis.

As we grow more comfortable with the new format, the variety of items in each issue will increase. You can contribute. Send in your comments, notices, and letters. (See the box in the left-hand column.) Both general and technical articles will be welcome. Authors of technical articles are urged to obtain peer review and to mention the reviewers in acknowledgments.

Upcoming articles will cover such subjects as nonpoint source pollution, Gray Butte limestone, and the John Day gold dredge. Former State Geologist Ralph Mason promises book reviews.

The March issue will bring you the Department's annual reports on Oregon's mineral and metallurgical industry, mined land reclamation, geothermal energy, and oil and gas exploration. The writers will be able to treat these topics more comprehensively and accurately by waiting until all the data has been compiled before beginning their own articles.

Remember to keep us informed of your whereabouts. The U.S. Postal Service will not forward second class mail, even when it is a first class magazine.

A.B.

Silver Falls State Park

by Michael Freed, Department of Resource Recreation Management, Oregon State University

This article introduces the reader to the general geology of one of Oregon's most popular state parks. A more technical discussion of the stratigraphy of the Columbia River Basalt Group in western Oregon follows on page 11.

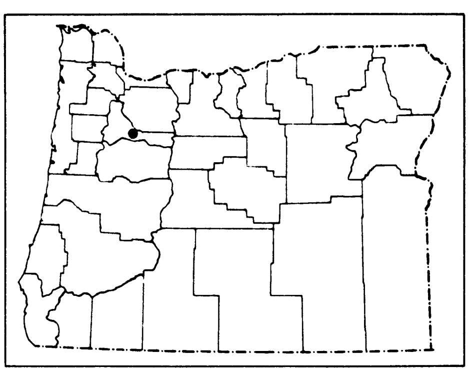
INTRODUCTION

Silver Falls State Park embraces one of the greatest concentrations of waterfalls in the West. Within a short radius, 14 falls tumble over the narrow, rocky courses of the North and South Forks of Silver Creek; dense groves of old growth timber, dotted by sunny meadows, surround the misty canyons. It took millions of years of rock and soil deposition and subsequent erosion to form this unique landscape. A 7-mi loop trail makes it possible to observe traces of the long geologic history at close range and to enjoy a rich variety of plant and animal life.

Largest of all Oregon's state parks, Silver Falls lies about 30 mi east of Salem in the foothills of the Cascade Mountains. The park is easily accessible by State Highway 214 and remains open all year.

THE BEGINNINGS

The oldest rocks in the park date back to the Oligocene, more than 26 million years ago, when a sea covered most of western Oregon and the Coast Range was an archipelago. Marine sediments, shown as "Tm" on the geologic map, were deposited in the Silver Falls area. The ocean receded, and the Oligocene sandstone was tilted and deeply eroded.



Index map showing location of Silver Falls State Park, Oregon.

THE UPPER MIOCENE

About 15 million years ago, during the Miocene, a series of basaltic lava flows called the Columbia River Basalt Group erupted from great fissures or cracks in the ground and then covered over 50,000 sq mi of portions of Oregon, Washington, and Idaho. Silver Falls State Park is located on the western edge of the plateau formed by these flows, labeled "Tcr" on the geologic map. Although the exact source of the specific flows found in Silver Falls State Park has not yet been determined, swarms of feeder dikes near Monument, La Grande, and Grand Ronde, eastern Oregon; near Yakima, Washington; and along the Oregon and Washington coasts indicate former centers of igneous activity. No other area with such voluminous flood basalt flows is known to exist in the continental United States.

Although each individual Columbia River Basalt flow is chemically homogeneous, various zones within a flow may differ in appearance. As lava cools it shrinks, and tensional stresses within the flow produce fractures called joints. Because various parts of the flow cool at different rates, zones with distinct jointing patterns may often develop within any one flow. For example, slow cooling just above the base of a thick flow may result in very regular vertical jointing, often producing a zone with six-sided columns that together form a colonnade. Elsewhere in the flow, very irregular and closely spaced joints may combine to form the entablature. Either the entablature or the colonnade may appear more than once in a flow and may be thick, thin, or absent.

Where the lava was highly charged with gas, gas bubbles remaining throughout the cooling process produced holes called vesicles within the rock. Basalt with many holes is described as vesicular basalt.

During the several-thousand-year intervals between basalt flows, soil zones developed on the surfaces of previous flows. These zones are now represented by thick interbeds of soil, sand, silt, and organic material, parts of which were "baked" by the heat of a new lava flow entering the area.

All these features can be found within the park boundaries. At least three Columbia River Basalt flows have been observed in this area, and Barlow (1955) describes five separate flows at South Silver Creek Falls.

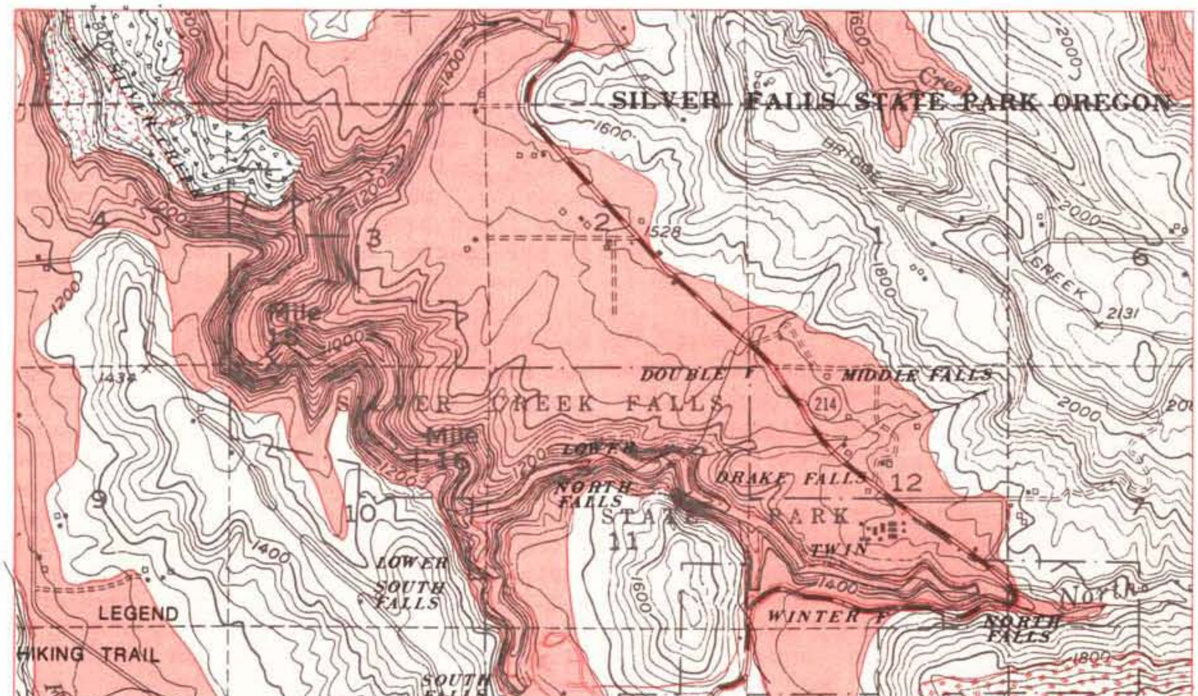
THE PLIOCENE AND PLEISTOCENE

During the Pleistocene, volcanoes to the east blanketed the Silver Falls area with lava flows, breccias, and tuffs of the Sardine Formation. Two of the five Sardine Formation subunits have been mapped in Silver Falls State Park and are indicated on the geologic map: the massive pumice tuff, basaltic andesite flows, and agglomerate-conglomerate beds are called the Fern Ridge tuffs (Thayer, 1939) and are labeled "Tst" on the geologic map; pyroxene andesite flow rock, labeled "Tsa", overlies the Fern Ridge tuff. Although these rocks were deeply eroded during the Pleistocene and relatively little of the softer units remains exposed today, the Fern Ridge tuff and associated rocks may be seen at the North Falls parking lot.

RECENT TIMES

The 14 waterfalls along the North and South Forks of Silver Creek are of more recent origin, and the story of their forma-

GEOLOGIC MAP OF CANYON TRAILS AREA, SILVER FALLS STATE PARK. (AFTER HAMPTON, 1972)



LEGEND

Symbol	Description
Qls	*Quaternary landslides*
Tsa, Tst	*Sardine Formation* *Tsa, andesite flow rock* *Tst, Fern Ridge tuff*
Tcr	*Columbia River Basalt*
Tm	*Marine sandstone, siltstone, and tuff*

-------- *Hiking trail*

tion is of particular interest to park visitors.

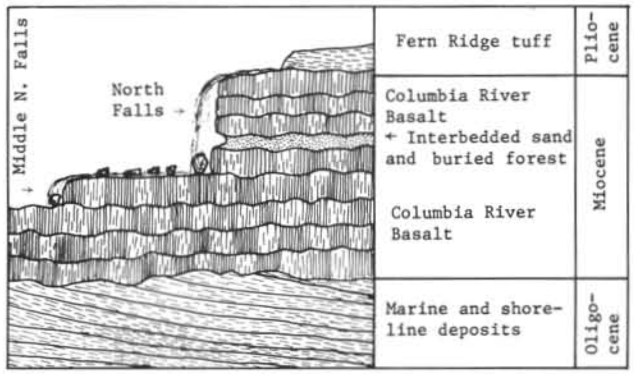
A tributary stream generally cuts its channel as rapidly as the main stream it joins. But in Silver Falls State Park, where the streams flow over Columbia River Basalt, the smaller volume side streams have not been able to keep up with the downcutting action of the main stream and have been left hanging, forming waterfalls. Fifteen such waterfalls have evolved in the park and will survive until the streams all cut through the basalt to the softer sedimentary rock beneath.

At South Falls, where the water drops 177 ft to carve a deep, beautiful plunge pool, erosion from the sediment-laden waters has undercut softer rock beneath the basaltic lip to form a cavern. This cavern is continually being enlarged by the weathering action of mist, lichens,

Aerial view of South Falls and surrounding countryside. (Photo courtesy Oregon State Highway Commission)

and water percolating from above. Manganese, silica, and iron have been leached out and redeposited on the ceiling. Gaping holes, called erosional chimneys, are formed by continual enlargement of cracks and fissures under the attack of ice and percolating waters.

At North Falls, the relatively rapid breakdown of a thick bed of sandstone under the resistant basaltic caprock has created



Sketch of North Falls in cross section.

Overhang of North Falls amphitheater.

a spacious amphitheater, more than 300 ft wide, behind the waterfall. Indians are said to have used this cavern for ceremonial purposes.

North Falls amphitheater, formed by the erosion of soft sediments of interbed deposited between two Columbia River Basalt flows.

The cavern and the tree casts in its ceiling tell an interesting story. An ancient stream flowing on the surface of an old Columbia River Basalt flow laid down about 20 ft of sand and silt. Eventually, a forest grew on this sedimentary surface. Later, another Columbia River Basalt flow engulfed the forest and baked the soil, but since the tree trunks were not instantly carbonized, the lava around them cooled and hardened quite quickly, leaving straight chimney-like holes with bark ridges.

Evidence of the wide and powerful waterfalls of the glacial period can best be seen at North and South Falls. At North Falls the stream once flowed in a much wider channel, but now water flows through only a notch in the lip of the cliff. The older and wider river bed cut by glacial melt water can still be seen etched into the basalt on either side of the notch.

Tree casts at North Falls. This view is looking directly overhead at holes formed when standing Miocene trees were engulfed by Columbia River Basalt which cooled and hardened before trees burned.

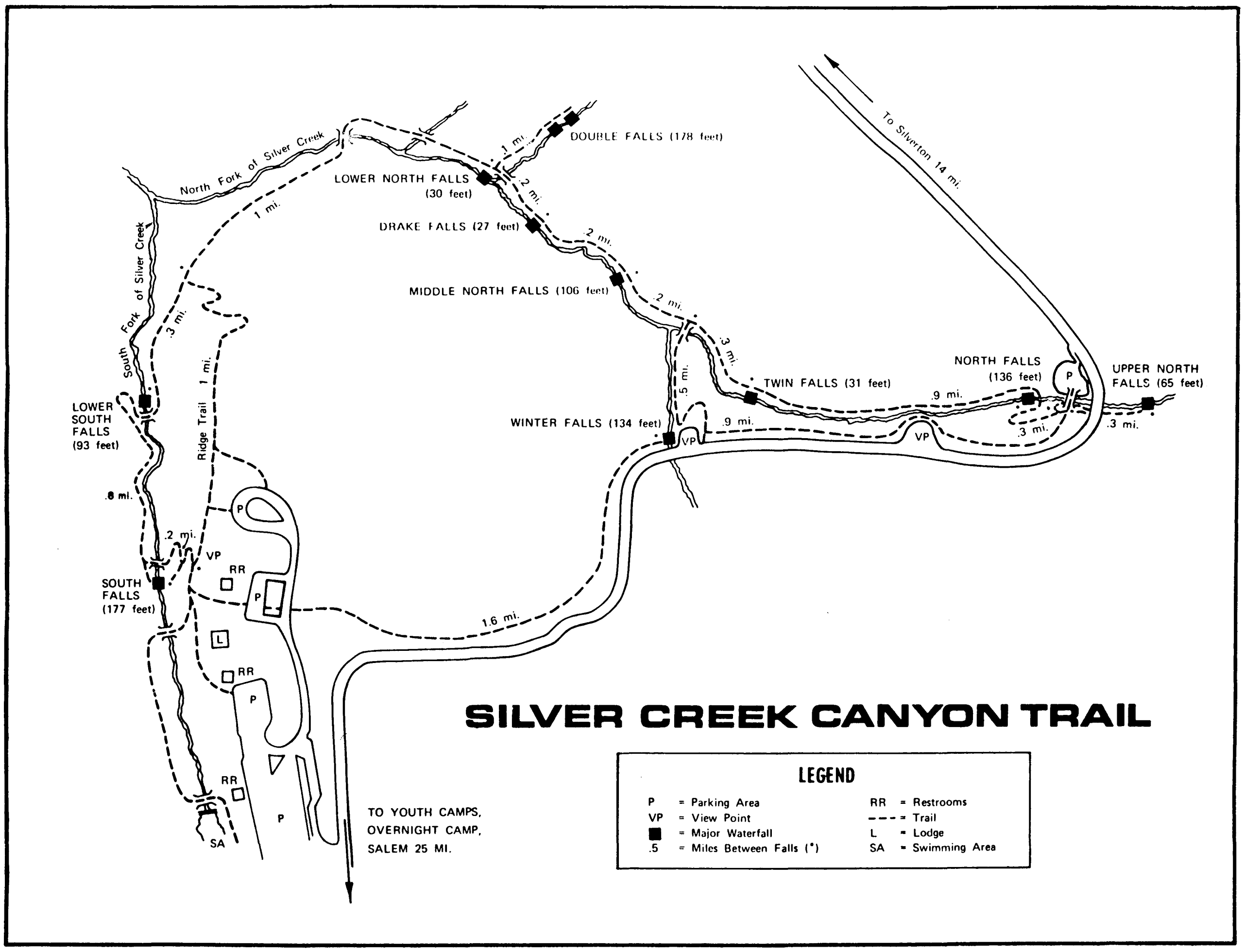
In its early youth, even the main channel of Silver Creek probably dropped over a basalt cliff into a deep gorge on its way to the Willamette River. Those falls gradually receded, cutting back upstream through the lava and finally branching into the North and South Forks of Silver Creek. As the falls on North and South Forks worked headward to their present positions, smaller falls developed on the tributary creeks. Huge basaltic boulders, fallen remnants of previously overhanging caprock broken off during the upstream movement of the falls, lie near the present-day plunge pools and for a long distance downstream.

The headward erosion of the falls will continue toward the Cascades until they reach the place where Columbia River Basalt thins out against the tuffs and other volcanic rocks. Eventually, the falls in the park will cut through the remaining basalt layers and then will disappear.

SILVER CREEK CANYON TRAILS

One must go down into the gorges and follow the Silver Creek canyon trails to see the geology of Silver Falls State Park. There are several routes of varying lengths. To see all the points of special interest, one must take the 7-mi hike leading directly under all the major falls in the canyon. It begins with a descent into the canyon of the South Fork along a series of switchbacks notched into the hard layers of lava. Small gas-bubble holes pockmarking the basalt along the trail indicate the top of a flow. The path leads into the cavern behind South Falls, where percolating water has enlarged joint intersections to form erosional chimneys. The falls flow over a well-developed entablature.

Leaving the cavern, the trail continues down along the left bank of South Fork and passes under Lower South Falls. Here, the stream cascades over the entablature of an older and lower basalt flow. After crossing South Fork again, the trail goes through a wooded hillside and then drops to the North Fork, crossing to its right bank by means of a rustic foot bridge.



(Map courtesy Oregon State Parks)

A little farther on are Lower and Middle North Falls. Along the way, one passes smaller falls that have been formed by tributary streams. Heights of the falls in the park are summarized in the following table:

Heights of falls in Silver Falls State Park

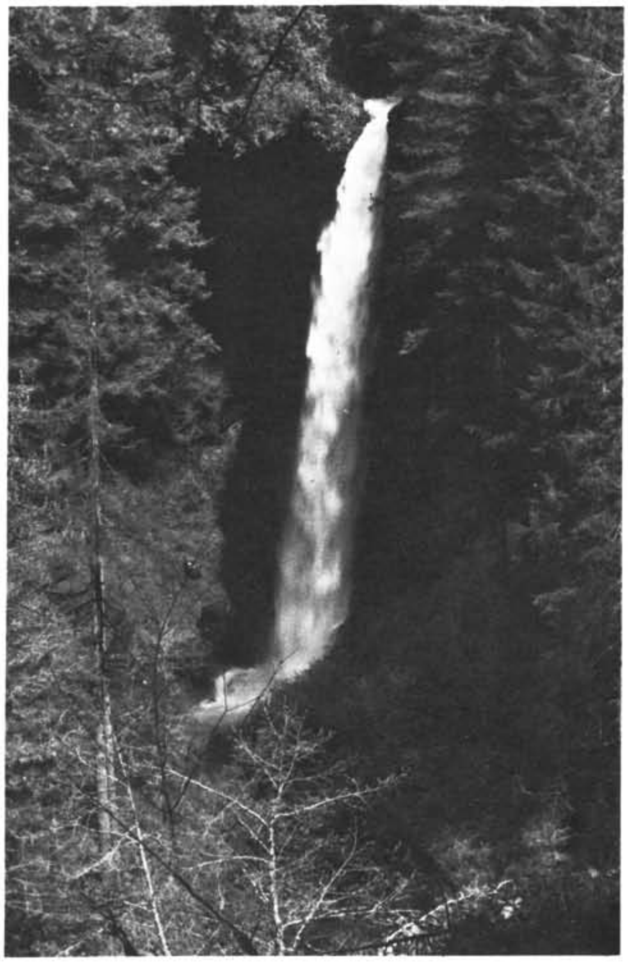
Location	Name of falls	Height (ft)
Above junction of South and North Forks	North	136
	Upper North	65
	Twin	31
	Winter	134
	Middle North	106
	Drake	27
	Double	178
	Lower North	30
	Lower South	193
	South	177
Below junction of South and North Forks	Crag	12
	Elbow	20
	Canyon	10
	Lisp	5
	Sunlight	5

At North Falls, a drop of 136 ft, the trail leads behind the roaring water again and into the large amphitheater carved out of the thick sedimentary layer beneath the capping basalt. Looking up at the ceiling, one can see the tree casts of an ancient forest, the baked contact zone of lava over soil, and large toothlike projections of basaltic columns. The trail then rises to the canyon rim by steps and runs parallel to the highway back to the starting point at South Falls.

FLORA AND FAUNA

The abrupt and precipitous canyons and waterfalls of the park have created a unique, moist environment with deep afternoon and morning shade, unusual spray and mist zones, and numerous rivulets, creeks, and streams. This environment provides an ideal, protected niche for a wide variety of plants and animals.

Drake Falls, which flows over Columbia River Basalt entablature. (Photo courtesy Oregon State Highway Commission)



North Falls. Note stream-cut notch at top of falls. (Photo courtesy Oregon State Highway Commission)

Most types of wildlife of the Cascade foothills are found here; and in addition, there are specialized forms, such as ground beetles, which exist only in the spray zones of waterfalls. Several good guides to the wildlife of Silver Falls State Park are listed in the reference section of this article.

HISTORY OF THE PARK

The first people to visit the Silver Creek area may have been nomadic Indian bands passing through on their way to the coast. No tribes are known to have settled for extended periods, although the park area did fall within the general territory of the Kalapuya Indians (Santiam dialect). The proposed Indian Ridge Trail follows several sections of these old Indian pathways.

Reliable records date back only to 1846, the year the town of Milford was founded on Silver Creek about 2 mi east of Silverton. Milford, a boom town set in motion by a logging enterprise, continued until about the time the park was established. The Silver Falls area, a favorite retreat for hunters and fishermen, was used for recreation for some 50 years before the state acquired the land. Unfortunately, these resources were destroyed by irresponsible logging and burning practices in the watershed.

Samuel Boardman, known as the father of the Oregon State Parks system, has left interesting notes and accounts of amusing incidents in the history of the park. The following excerpts are from a letter he wrote to his successor, Chester A. Armstrong:

"On a rainy fall day of 1929, I paid my first visit to the South Falls of Silver Creek. The road from Silverton was a country dirt road, right or left angling at every corner briar bush. . . . As I started to enter the road into the falls, a portly, elderly lady signaled for a stop and came up to the car. She stated I would have to pay ten cents in order to go on in and see the falls. She worked on a five percent commission from Mr. Geiser, the landowner, and would make from one to two dollars a day on weekends. . . .

"In the summer of 1931, the Commission approved my recommendation for the purchase of the Geiser property containing one hundred acres upon which the South Falls was located. This was the nest egg which hatched into a complete Silver Falls State Park. . . .

"Before we acquired the South Falls, Geiser advertised circus stunts. He built a low dam just above the lip of the South Falls, got a chap with a canoe. Ran a wire through a ring on the bow of the canoe, anchored the wire to the bottom of the pool, a 184-foot drop. The voyager got into the padded canoe, the dam was pulled. The canoe failed to follow the wire, but turned sideways. The voyager was fished out with a set of broken ribs. The canoe demolished, Geiser couldn't get any more human guinea-pigs, so he built a track in the bottom of the creek, sent ancient cars over the brink for the plunge. These Fourth of July stunts drew very well. I believe the entrance fee was twenty-five cents.

"In March, 1935, the Commission signed up with the U.S. Army for the establishment of a CCC camp at Silver Falls State Park. The Army was to have supervision of 200 boys while off duty. The National Park

Service was to have supervision of the boys during the eight hour working period.

"The parks of the state up to the time of the CCC boys had little development. With the advent of the camps, the CCC boys actually constructed the development foundation of our park system."

Silver Falls State Park now spreads over 2,270 acres and is a favorite among Oregon's state parks. Footpaths, bicycle roads, and equestrian trails make it easy to explore its wildlife and geological features and to take advantage of the excellent provisions for recreation.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of the following students in the preparation of this article: Karen Anderson, Kathy McGehee, Arn Hasslen, Jean Carter, Jane Renner, Cass Moore, Janice Brown, Cynthia Cowan, and Brooks Abbruzzese.

We are grateful to Raymond E. Corcoran, former State Geologist, for his guidance in understanding the geology of Silver Falls State Park.

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New geothermal and asbestiform minerals open-file reports released

Economic Geologist Jerry J. Gray's "Reconnaissance Study of Oregon's Stone Quarries and Asbestiform Minerals Occurrences Within 10 Miles of Serpentinite" has been released as the Department's Open-File Report O-78-5.

Maps showing locations of serpentinite rock, asbestos occurrences, and nearby stone quarries of southwestern Oregon and of northeastern Oregon accompany the text.

O-78-6, produced by the Department in cooperation with the USGS and Northwest Natural Gas Co., is "Geophysical Logs, Old Maid Flat #1, Clackamas County, Oregon."

This report is a compilation of geophysical logs, including temperature surveys. The detailed information can be used by geologists, engineers, developers, and government agencies searching for geothermal energy in Oregon.

Both reports can be purchased from the Department's Portland Office. O-78-5 costs $2.50; O-78-6 is priced at $20.00.□

Columbia River Basalt Group stratigraphy in western Oregon

by Marvin H. Beeson and Michael R. Moran, Earth Science Department, Portland State University

This article is taken from a publication, in preparation, on the stratigraphy and structure of the Columbia River Basalt Group around Mount Hood, by M.H. Beeson and others. The study is part of a research effort on the geothermal resource assessment of Mount Hood Volcano, Cascade Range, Oregon, being undertaken jointly by the U.S. Geological Survey, the U.S. Forest Service, and the Oregon Department of Geology and Mineral Industries. The U.S. Department of Energy is supplying funds for the program. Results of the Columbia River Basalt Group study will be published later this year.

INTRODUCTION

The Miocene Columbia River Basalt Group of Oregon, Washington, and Idaho is an accumulation of tholeiitic flood basalt flows covering approximately 2×10^5 km^2 (Figure 1; Waters, 1962). These fluid flows spread over this region, the Columbia Plateau, as nearly horizontal sheets, attaining a total thickness of at least 1,500 m near Pasco, Washington (Asaro and others, 1978). They were extruded from large north- to northwest-trending fissure systems in the eastern half of the plateau (Waters, 1961; Taubeneck, 1970; Swanson and others, 1975) between approximately 16 and 6 million years ago (Watkins and Baksi, 1974; McKee and others, 1977).

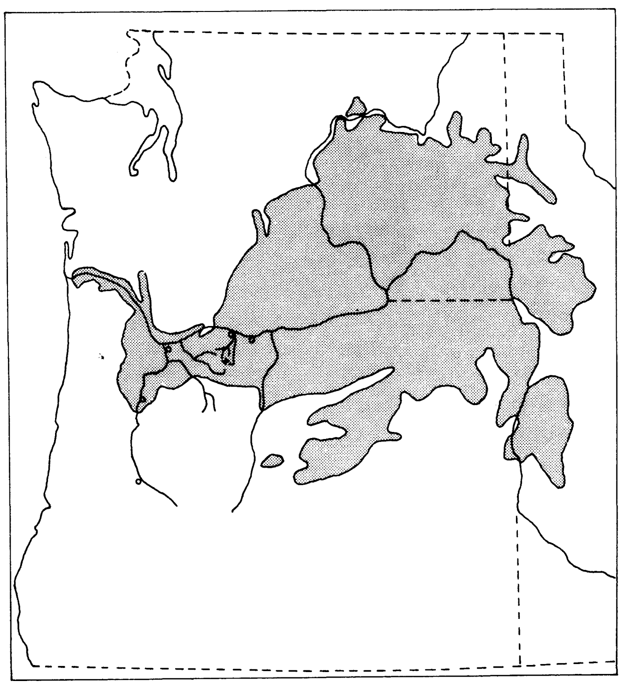


Figure 1. Distribution of Columbia River Basalt Group in Oregon, Washington, and Idaho. (After Waters, 1961)

The stratigraphic subdivisions and nomenclature have undergone a number of revisions and refinements as mapping has progressed and as modern geochemical and paleomagnetic data have accumulated. Many contributions have been made to the Columbia River Basalt Group stratigraphy, some of the more noteworthy being Waters (1961, 1962); Mackin (1961); Schmincke (1967); Wright and others (1973); and Nathan and Fruchter (1974). Recently a revised nomenclature for the Columbia River Basalt Group has been approved by the U.S. Geological Survey (Figure 2; Swanson and others, in press). This nomenclature, a rather complete representation of the stratigraphy of the Columbia River Basalt Group in the Columbia Plateau, is used here. In this revision, the Group is divided into five formations. Two of these, the Imnaha Basalt and the Picture Gorge Basalt, are restricted to the southeastern and southern portions of the province, respectively; the remaining three, the Grande Ronde Basalt, the Wanapum Basalt, and the Saddle Mountains Basalt, are grouped together as the Yakima Basalt Subgroup. All of the Columbia River Basalt Group flows identified west of the axis of the Cascade Mountains belong to this subgroup, with the exception of flows of the Prineville chemical type, discussed below, which are not included in the revised nomenclature. The coastal Miocene basalts of Oregon and Washington form three distinct stratigraphic units that are consanguineous with the three formations of the Yakima Basalt Subgroup (Snavely and others, 1973).

Some of the basalt flows originating in the eastern part of the plateau flowed into western Oregon through a topographic low in the ancestral Cascade Mountains. This low extended from the Clackamas River drainage on the south to the present Columbia River Gorge on the north. The Yakima Basalt Subgroup, about 1,500 m thick in the Pasco Basin, thins to approximately 550 m in

Series		Group	Sub Group	Formation	Member or Flow	K-Ar Age (m.y.)	Magnetic Polarity
Miocene	Upper Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Lower Monumental Member	6	N
					Erosional Unconformity		
					Ice Harbor Member Basalt of Goose Island	8.5	N
					Basalt of Martindale	8.5	R
					Basalt of Basin City	8.5	N
					Erosional Unconformity		
					Buford Member		R
					Elephant Mountain Member	10.5	N, T
	Middle Miocene				Erosional Unconformity		
					Mattawa Flow		N
					Pomona Member	12	
					Erosional Unconformity		
					Esquatzel Member		N
					Erosional Unconformity		
					Weissenfels Ridge Member Basalt of Slippery Creek		N
					Basalt of Lewiston Orchards		N
					Asotin Member		N
					Local Erosional Unconformity		
					Wilbur Creek Member		N
					Umatilla Member		N
					Local Erosional Unconformity		
				Wanapum Basalt	Priest Rapids Member		R_3
					Roza Member		R_3 T
					Frenchman Springs Member		N_2
					Eckler Mountain Member		
					Basalt of Shumaker Creek		N_2
					Basalt of Dodge		N_2
					Basalt of Robinette Mountain		N_2
				Grande Ronde Basalt			N_2
	Lower Miocene		Picture Gorge Basalt				R_2
							N_1
							R_1
				Imnaha Basalt			R_1
							T
							N_0
							R_0

Figure 2. Columbia River Basalt Group stratigraphy. Bars indicate members occurring in western Oregon. (After Swanson, 1978)

the Cascade Range. Many stratigraphic members recognized on the plateau are not present or comprise fewer flows in western Oregon. The Saddle Mountains Basalt, which ranges from 150 to 275 m thick in the Pasco Basin, has not been found in the Cascade Range, even though the Pomona Member is present near the Columbia River in the Coast Range of Oregon and Washington (Snavely and others, 1973; Kienle, 1971). The members of the Yakima Basalt Subgroup that occur in western Oregon are indicated in Figure 2.

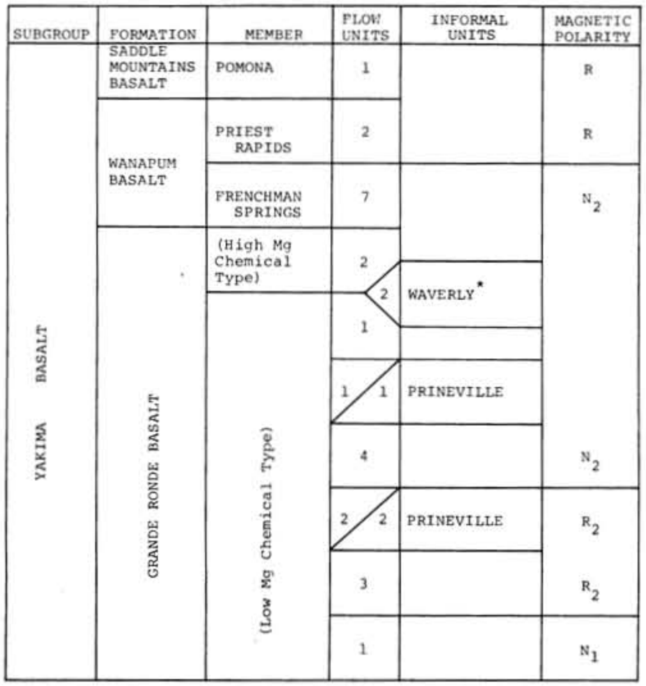
In western Oregon, the Columbia River Basalt Group comprises approximately 21 basalt flows which may be divided into three formations of the Yakima Basalt Subgroup (Figure 3). Distinctive characteristics of each member and of other informal subdivisions are given in Figure 4. These units are tentatively identifiable in the field on the basis of jointing characteristics, magnetic polarity, grain size, and the presence or absence of large plagioclase phenocrysts. Laboratory data, especially major or trace element chemistry, are necessary for more accurate determinations.

GRANDE RONDE BASALT

Grande Ronde Basalt is the most widespread of all the Columbia River Basalt Group formations in western Oregon, occurring almost everywhere the Columbia River Basalt has been mapped. Of the four magnetic polarity intervals formally recognized within the Grande Ronde Basalt, only the oldest, a reversed interval (R_1), has not been found in western Oregon. The oldest normal interval (N_1) is represented by a single flow that occurs at the bottoms of the sections in Multnomah Creek and in the Clackamas River (Anderson, 1978).

Grande Ronde Basalt may also be divided chemically on the basis of magnesium content into "Low Mg" and "High Mg" flows (Figure 3). In western Oregon, two High Mg flows occur as the top two flows of the Grande Ronde Basalt. Because of their distinctive jointing patterns and textures, the two High Mg flows are generally distinguishable in the field from the Low Mg flows, and this informal subdivision is therefore useful for geologic mapping in western Oregon. In the rest of the Columbia Plateau, however, the High Mg flows may also occur lower in the Grande Ronde Basalt section (D.A. Swanson, personal communication).

The Grande Ronde Basalt section in western Oregon also contains localized units that do not occur extensively in the plateau and are not formally recognized. In



the Clackamas River area, two flows of the chemically distinctive Prineville chemical type (Uppuluri, 1974) occur at the top of the second reversed (R_2) section (Anderson, 1978). One Prineville flow, probably an N_2 flow occurring near the top of the Low Mg Grande Ronde Basalt, has been found in a drill hole at Old Maid Flat, west of Mount Hood. The Prineville chemical-type flows probably originated near Prineville, where 13 flows are exposed (Uppuluri, 1974), and spread northward and westward, onlapping and interfingering with flows of Low Mg Grande Ronde Basalt. Prineville flows have not been found in the Willamette Valley, but the lower part of the Grande Ronde section is not exposed in the Portland area, and few chemical analyses have been

← Figure 3. Stratigraphy of Columbia River Basalt Group in western Oregon. Informal units have limited areal extent.

STRATIGRAPHIC UNIT	FIELD CRITERIA Jointing, polarity & lithology	LABORATORY CRITERIA Geochemistry** & petrography
Pomona Member	Blocky to columnar jointing Reversed polarity Clear plagioclase phenocrysts (3-4 mm) Clots of plagioclase and pyroxene	Sm <5 La <20 Fe <8%
Priest Rapids Member	Reversed polarity Coarse sugary texture	Sm >7 La 25-30 Sc 35-40 Eu ≥2.5
Frenchman Springs Member	Well-formed colonnade Normal polarity Texture often coarse Large (1-cm) plagioclase phenocrysts	Sm >7 La 25-30 Sc 35-40 Eu ≤2.5
*High Mg Grande Ronde Basalt	Blocky and platy jointing Normal polarity Coarse texture	Sm <6 La 20-24 Sc 35-40
*Waverly flows	Upper flow - very poorly jointed Lower flow - large columns with platy jointing Normal polarity	Sm <6 La 15-18 Upper flow - clots of plagioclase and pyroxene Lower flow - pilotaxitic
*Low Mg Grande Ronde Basalt	Well-formed entablature Fine texture	Sm <7 La 25-30 Sc 30-35
*Prineville flows	Well-formed blocky to wavy colonnade Fine texture	Ba∿2,000 Eu >4 Co <35 Abundant apatite laths

* Informal units.
** Geochemical data obtained by neutron activation analysis. All data in parts per million except where specified.

Figure 4. Distinctive characteristics of western Oregon Columbia River Basalt Group stratigraphic units. Field criteria allow tentative identification; laboratory criteria are usually needed for positive identification.

made on Columbia River Basalt from other parts of the valley. No Prineville flows are known to occur in the Bull Run Watershed (B.F. Vogt, personal communication) or in the Columbia River Gorge (Beeson and others, 1976).

In the Waverly Heights area near Milwaukie, Oregon, two flows which have been informally designated the Waverly flows (Beeson and others, 1976) occur between the High Mg and the Low Mg Grande Ronde Basalt flows. They were localized by structure and/or erosional lows which existed at that time. Chemically they are very similar to the Low K_2O Grande Ronde Flows that occur at or very near this same stratigraphic horizon in the Pasco Basin (Ledgerwood, 1978) and along the Snake River in Washington. The Waverly flows are also similar chemically to the older Imnaha Basalts.

WANAPUM BASALT

The Frenchman Springs Member of the Wanapum Basalt is widespread in the Columbia River Basalt occurrences in western Oregon. It is not present along some structural highs such as the Portland Hills anticline, either because it was excluded by developing structures or because it was once present and has been eroded away. In the Columbia Plateau, Grande Ronde and Wanapum Basalt are separated by the Vantage interbed; in western Oregon, this same contact is marked by a distinctive weathering surface and interbed of carbonaceous material. Interbeds occur between other Columbia River Basalt flows in western Oregon, but because this interbed is characterized by deep weathering, structural deformation, and sedimentary deposits, it must represent a longer time interval. Tree molds and carbonaceous material are common at this boundary. The first two Frenchman Springs flows above it contain plagioclase megaphenocrysts which aid in positive stratigraphic determination.

The Priest Rapids Member is present in the Bull Run Watershed (B.F. Vogt, personal communication) and at Crown Point on the Columbia River as one or possibly two intracanyon flows which filled what may have been the first stream channel to have been cut into Columbia River Basalt in this area. Priest Rapids flows have not been found in any other location in western Oregon.

SADDLE MOUNTAINS BASALT

The Pomona Member of the Saddle Mountains Basalt occurs along the lower Columbia River of Oregon and Washington. This flow probably traversed the Cascade Range as an intracanyon flow whose course is yet to be discovered. No Pomona flows have been found in the Cascade Range or in the Portland area.

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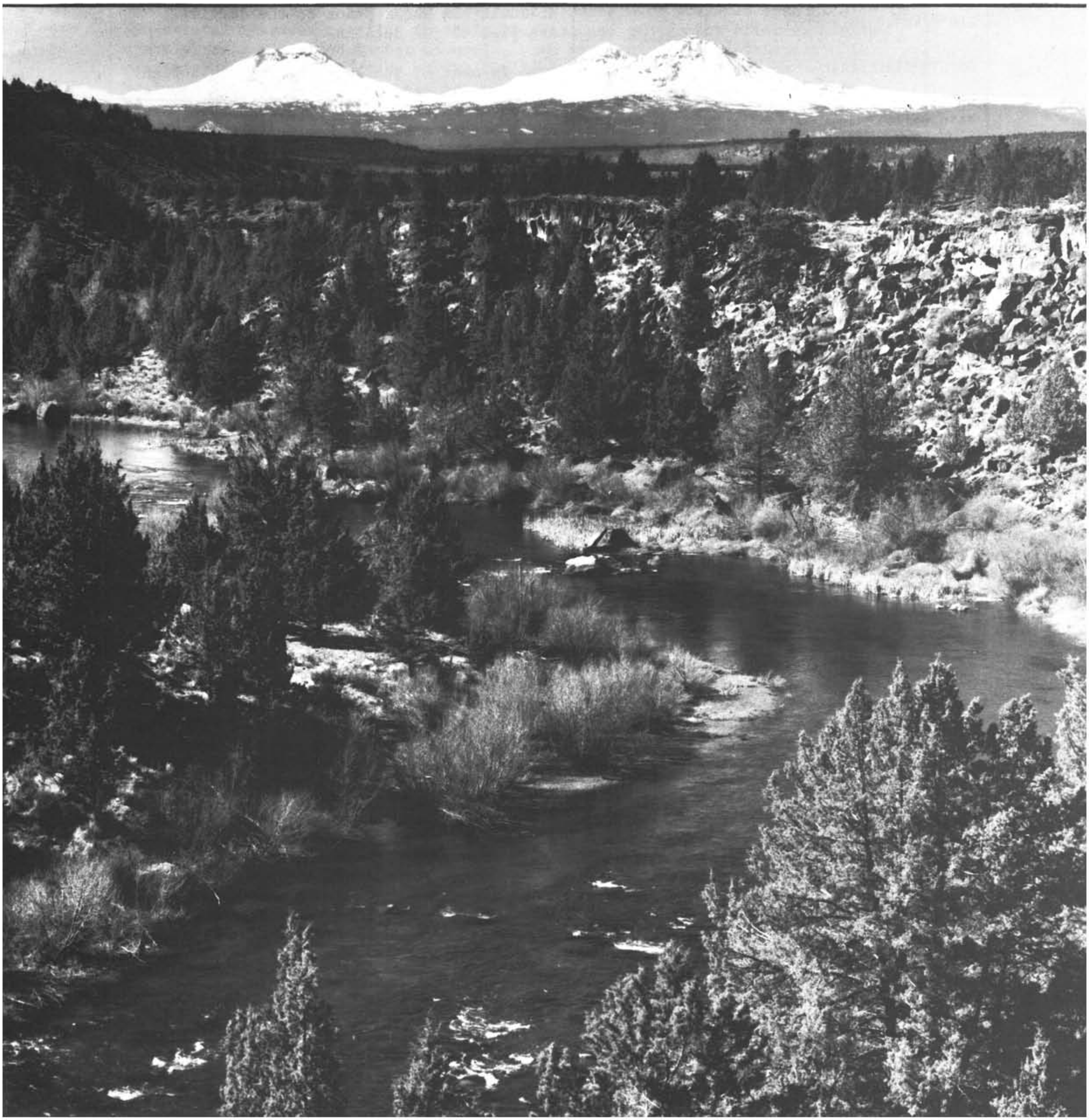

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To our readers:

Response to our new format has been enthusiastic, and we thank you all for your interest. This month we are including upcoming meeting announcements on page 32. If you want your geology or mineral-industry meeting announced, we need the information at least six weeks prior to the meeting. See page 32 for details.

As most of you know, geology is a highly interpretive science, and all of you may not agree with all of what our authors say about Oregon geology. We invite written discussion about geologic interpretations printed in OREGON GEOLOGY and from time to time plan to print these letters. We will also give our authors the opportunity to respond in writing.

Next month, OREGON GEOLOGY will contain the annual summaries of Oregon's mineral and metallurgical industry; oil, gas, and geothermal exploration; and mined land reclamation.

The Department has several current projects that are part of our ongoing survey of the State's geology and mineral resources: Josephine County mineral inventory, Blue Mountains mapping, economic demand model of sand and gravel, Mt. Hood geothermal assessment, statewide low temperature geothermal inventory, Coos Basin oil and gas, waste disposal, Clackamas County geologic hazards, and Benton County geologic hazards. These projects will be discussed individually in detail in future issues of OREGON GEOLOGY.

COVER PHOTO

Three Sisters form backdrop for Deschutes River, one of Northwest's best known trout fishing streams, near Redmond, central Oregon. Concepts presented in article beginning on page 19 represent significant step toward development of unified interpretative framework for maintaining fishable and swimmable waters in Oregon. (Oreg. Dept. Transportation photo)

CONTENTS

The assessment of nonpoint source pollution in Oregon

by Gary L. Beach, Geographer, Oregon Department of Environmental Quality

The following article describes a recent effort to assess nonpoint source pollution in Oregon. It is an excellent illustration of the way various agencies and disciplines can focus on a complex problem. No single discipline was dominant; each was essential to the successful completion of the project. From the discussion it is evident that geologic processes commonly viewed as geologic hazards have relevance to a wide variety of land and resource management concerns.

The Statewide and Basinwide Assessment reports were prepared specifically to aid natural resource agencies in their planning and management efforts. Consequently, only a limited number of copies were printed. Persons interested in obtaining further information on the 208 Assessment Project or on the locations where these two publications can be examined should write to Oregon Department of Environmental Quality, Water Quality Division, P.O. Box 1760, Portland, Oregon 97207.

INTRODUCTION

THE PROBLEM

Water is one of Oregon's most important natural resources. For many years now, Oregonians have met the challenge of maintaining a desirable natural environment and improving the quality of its water. But as urbanization and man's intensified use of rural land continues to increase, the deterioration of our valued waters is inevitable without specified planning and adequate management tools to guide decision-makers.

Recognizing the need to control accelerated land erosion and to restore the quality of the streams to acceptable levels, Congress in 1972 passed Public Law 92-500, the Federal Water Pollution Control Act Amendments. According to this law, by 1983 each state will determine ways to achieve "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water." In Section 208 of the Act, Congress further recognized that the proposed 1983 goal of fishable and swimmable waters could not be met by controls on point sources alone (e.g., end-of-pipe discharges from municipal waste treatment plants and industrial effluents). For the first time, the control of water pollution from more subtle and less obvious nonpoint sources will have been required by federal law.

Nonpoint source (NPS) pollution can be defined as adverse water quality conditions generated by the introduction of materials from diffuse origins, caused by man's planned or accidental activities on the land and in the stream. Erosion of the land surface that produces sediment in the streams is an example of a nonpoint source pollution problem.

THE SOLUTION

In Oregon, the Department of Environmental Quality (DEQ) was assigned the task of developing a water-quality management planning program to meet the ambitious objectives of Public Law 92-500 (Mullane and Beach, 1977, p. 15). These objectives require each state to:

(1) Identify and evaluate the nature and extent of present or potential NPS problems; and

(2) Develop and initiate processes, procedures, and methods to control, to the extent feasible, identified NPS problems.

Several aspects make this planning process unique:

(1) The emphasis on finding solutions that involve prevention rather than correction of NPS problems;
(2) The emphasis on state and local interagency planning rather than national planning;
(3) The emphasis on combating water pollution where it is most serious;
(4) The emphasis on public involvement throughout the entire planning process; and
(5) The emphasis on consideration of the quality of all stream segments, including small tributaries.

As a result of this mandate, DEQ's 208 Assessment Project, in cooperation with the Oregon Department of Geology and Mineral Industries and other natural resource agencies, developed several significant and far-reaching planning and management products and procedures. For the first time, a statewide inventory of NPS problems in Oregon has been completed. Also for the first time, a basinwide procedure that relates the dynamic natural processes on land and in streams to man's land management activities is available. The maps, guidelines, and resource tools developed represent the application of geo-based information specifically designed for aiding the control of erosion-related NPS problems, thereby improving the quality of Oregon's waters.

STATEWIDE ASSESSMENT

OBJECTIVES

The first phase of the Assessment Project was concerned with gathering all available information on the location, type, and severity of known or potential NPS problem areas throughout the State. This information could be used to prioritize management planning efforts aimed at understanding and controlling NPS problems and to provide other resource agencies with a means of designing their long-range planning goals as they relate to stream and water quality.

QUALIFICATIONS

Several important decisions were made by the assembled interdisciplinary team prior to data collection.

Stream quality versus water quality

First, focus was placed on the broader context of stream quality in preference to water quality. The inventory was concerned with the physical condition of the stream channel and surrounding banks as well as the quality of the water because many highly prized fish, such as trout and salmon, require stable bottom conditions for spawning, and all fish require suitable cover conditions for rearing. Geologic input is particularly significant in this kind of analysis.

Natural or man-caused pollution

Second, because of the statewide nature of the Assessment Project and severe time constraints imposed on data collection and analysis, it was impossible to determine the degree to which identified problems were natural or were man-caused. Therefore, much of the information presented in the report pinpoints the types and locations of problems without making the judgment as to whether nature or man is responsible for the adverse condition (Rickert and others, 1978b, p. 9).

Cause-and-effect relationship

Third, it was not the intent of the statewide assessment to show a cause-and-effect relationship between man's activities on the land surface and the subsequent impacts on stream quality. Because land use patterns and practices largely determine the degree of pollution in streams, generalized land use information was put on the problems maps to illustrate the relationship between man's use of the land (i.e., urban, agriculture, forest, and range) and the distribution and concentrations of identified NPS problem areas.

PROCEDURES

The information used in the statewide assessment was gathered from a technical questionnaire sent to federal, State, and local resource management agencies and from the public at meetings in each of Oregon's 36 counties. The information initially collected was validated through compilation, analysis, and review by local agency respondents and private citizens (Figure 1). The completed inventory maps were further reviewed by an Interagency Task Force, a Policy Advisory Committee, county water-quality committees, and DEQ water-quality specialists. The intent was to obtain a consensus of the known problem areas and develop confidence in the results.

RESULTS

The products of the statewide assessment are presented on a series of Oregon maps (scale 1:500,000), on two tables, and in a summary report. The maps are entitled:

(1) Stream-Bank Erosion,
(2) Sedimentation,
(3) Excessive Debris,
(4) Water Withdrawals Causing Stream-Quality Problems,
(5) Elevated Water Temperatures,
(6) Nuisance Algae or Aquatic Plant Growths,
(7) Composite Nonpoint Source Problems, and
(8) Erosion Potential-Sediment Yield.

The two tables summarize streams, stream segments, or water bodies in the state that have:

(1) Low-dissolved oxygen
(2) Excessive nutrients.

For the purposes of this paper, only the results of stream-bank erosion, sedimentation, and erosion potential-sediment yield are presented. The summary report by Rickert and others (1978b) contains detailed discussion of all the maps and tables.

Sedimentation

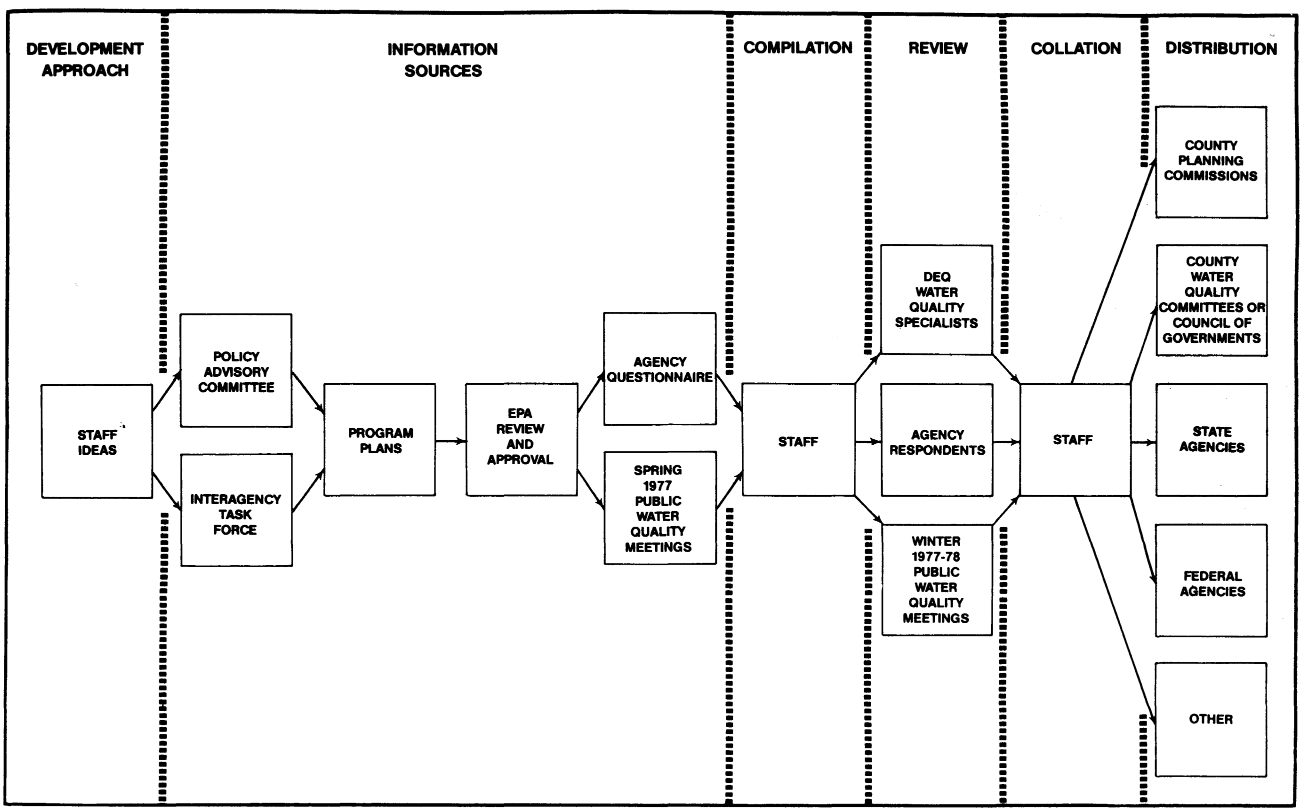
In this paper, sedimentation is defined as the presence in water of suspended or settled solids which interfere with its beneficial uses. Excessive sedimentation can adversely affect water supplies, irrigation, fish and aquatic species habitats, recreation, and aesthetics. Deposited sediment may also create a problem in maintaining navigation channels or may shorten the life and utility of lakes and reservoirs. The study clearly illustrated that excessive sedimentation is the most widespread and pervasive NPS problem in Oregon (Figure 2). Regional areas identified as having large concentrations of severe sedimentation problems include:

(1) Southwestern part of the North Coast Basin (largely centered in the Tillamook Burn area),
(2) Southeastern part of the Willamette Basin,
(3) Siuslaw River part of the Mid-Coast Basin,
(4) Main Stem and South Fork parts of the Umpqua Basin,
(5) Central part of the Rogue Basin,
(6) Southern part of Goose and Summer Lakes Basin,
(7) Crooked River part of the Deschutes Basin,
(8) Malheur Basin,
(9) Southern part of the John Day Basin, and
(10) Hood Basin.

Stream-bank erosion

Stream-bank erosion results from the movement and cutting of streams. This process involves the collapse of earth material and vegetation directly into streams. The potential for stream-bank erosion is determined primarily by bedrock characteristics,

Figure 1. Process used to develop Oregon's inventory of nonpoint source pollution problems.



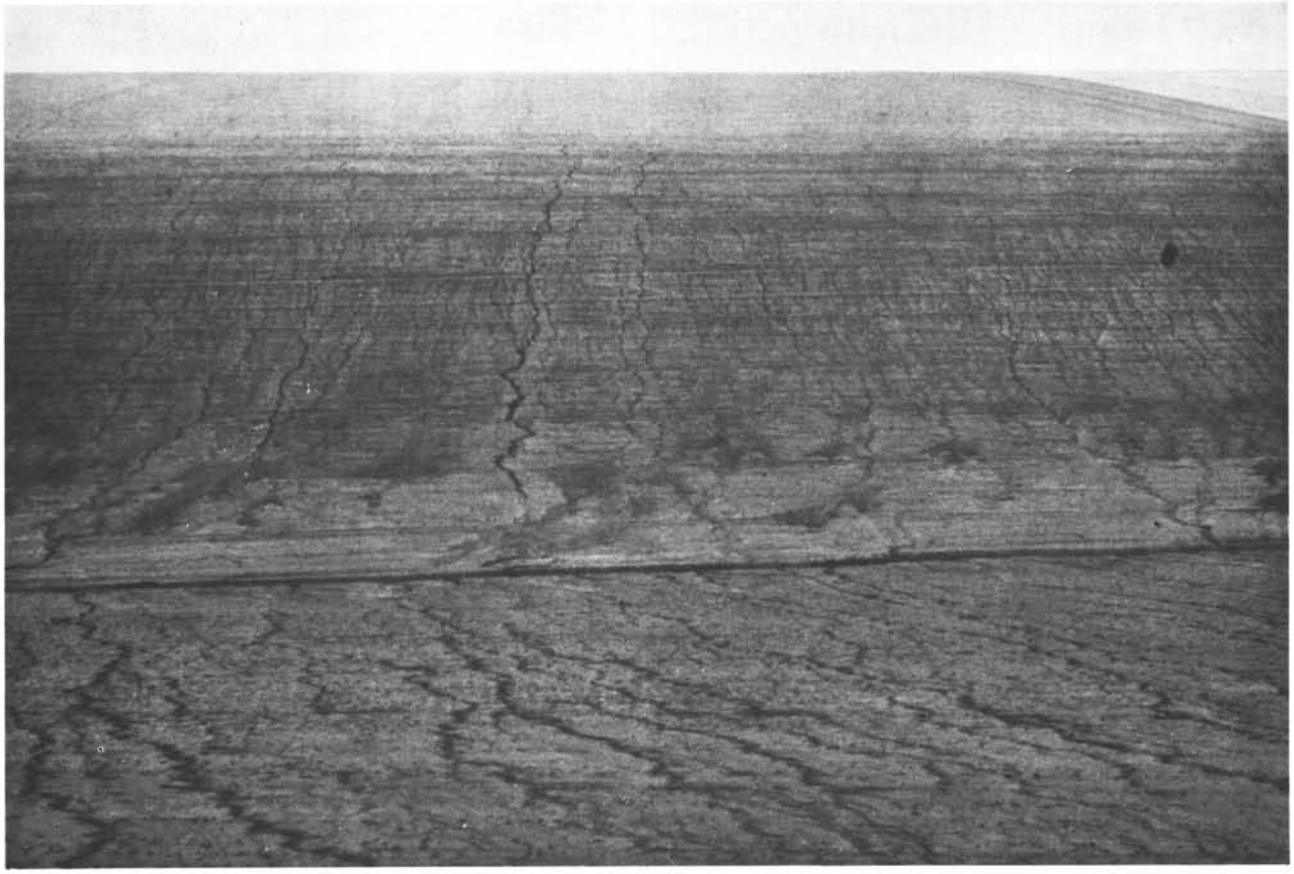


Figure 2. Sheet and rill erosion on exposed dryland wheat farm near Pendleton. Sediment derived from these loessal soils moves progressively downslope, entering intermittent and perennial stream channels. On land, sedimentation removes valuable topsoil and may lead to severe gully erosion unless prompt conservation practices are applied. In streams, sediment can change natural equilibrium and thereby destroy fish and aquatic specie habitats. (Photo courtesy John E. Jackson)

soil properties, and the degree of vegetation cover. When excessive or accelerated by man's activities, stream-bank erosion can destroy productive land and affect several beneficial uses of streams. Stream corridor activities that remove protective vegetation are prime causes of stream-bank erosion. This type of fluvial erosion may also be initiated by deflection of debris or sediment on the outside bends of streams and by mass wasting resulting from stream cutting (Figure 3). Regional areas of large concentrations of severe stream-bank erosion are:

(1) Southwestern part of the North Coast Basin,
(2) Yamhill River part of the Willamette Basin,
(3) South Fork part of the Umpqua Basin,
(4) Central part of the Rogue Basin,
(5) Southern part of Goose and Summer Lakes Basin,
(6) Crooked River part of the Deschutes Basin,
(7) Northern part of the Malheur Lake Basin,
(8) Malheur Basin,
(9) Umatilla Basin,
(10) Northern part of the John Day Basin, and
(11) Hood Basin.

Erosion potential-sediment yield

The purposes for producing an erosion potential-sediment yield map within this inventory phase were to:

(1) Identify general source areas for erosion-related NPS problems presented in the stream-bank erosion and sedimentation maps; and
(2) Show land management agencies where to focus their preventive and corrective programs for water-quality protection or improvement.

The Oregon sediment yield areas were taken directly from a map prepared by the U.S.D.A. Soil Conservation Service (1975), which protrays high, medium, and low sediment yield areas of the State.

The erosion-potential component of the DEQ map is a composite of data on three major types of erosion: surface erosion, gully erosion, and mass wasting. Thirteen erosion-potential units ranked in terms of the susceptibility of land to erode were interpreted through the procedure shown in Figure 4.

The first step in developing the map was the utilization of a land use map of Oregon (Pacific Northwest Regional Commission, 1975). The working hypothesis assumed agricultural land and rangeland (<20 percent slope) is dominated by surface erosion and forest land and rangeland (>20 percent slope) is dominated by mass wasting and gully erosion. Although almost all types of erosion will occur somewhere on land included within any one general type of land use category, at the statewide mapping scale used, the above assumptions about types of erosion are generally correct.

Surface erosion: Surface erosion categories were determined by combining generalized slope steepness with available data on the *R* (rainfall intensity) and *K* (soil texture) factors from the Universal Soil Loss Equation (U.S.D.A. Soil Conservation Service, 1976). By combining statewide information on these three factors, it was possible to define and rank seven categories of surface erosion potential for Oregon.

Mass wasting and gully erosion: The areas designated as being dominated by mass wasting and gully erosion were grouped and ranked into four mass-wasting and two gully-erosion categories, by using statewide overlay maps of climate (Loy, 1976) and geology (Walker, 1977; Wells and Peck, 1961). The

Figure 3. Nearly continuous stream-bank failure on Vester Creek, tributary to South Fork John Day River. Natural meadow in which stream flows has been disturbed by man's activities. Willows along stream channel have been disturbed, and the meadow has been drained, resulting in active downcutting by stream as it attempts to regain its dynamic equilibrium. This situation could have been avoided. (Photo courtesy David M. Anderson)

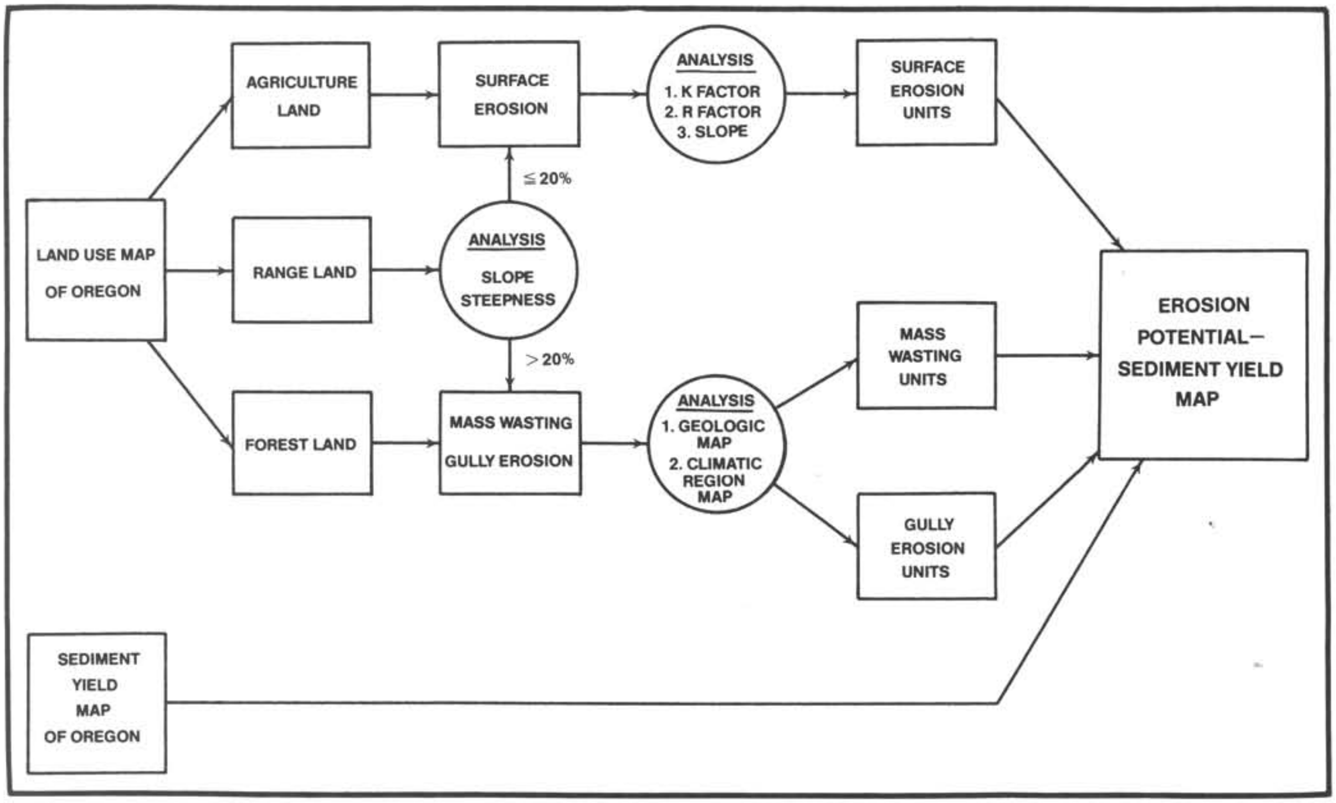


Figure 4. Procedure for producing erosion potential-sediment yield map of Oregon.

Oregon Department of Geology and Mineral Industries provided guidance on the mass-movement properties of various geologic units.

The relationship of climate to geologic bed rock accounts largely for the areal variation of specific landforms and geomorphic processes. The atmosphere provides energy and agents such as water, ice, and wind necessary for most weathering of the earth's surface. The bed rock provides material to be sculptured. As this interrelationship continues over time, distinctive landforms evolve. Under a certain set of climatic conditions, particular geomorphic processes predominate and give a regional character to the land surface, distinguishing it from other areas developed under different conditions. This explains, to a considerable degree, the type and distribution of mass wasting and fluvial erosional processes.

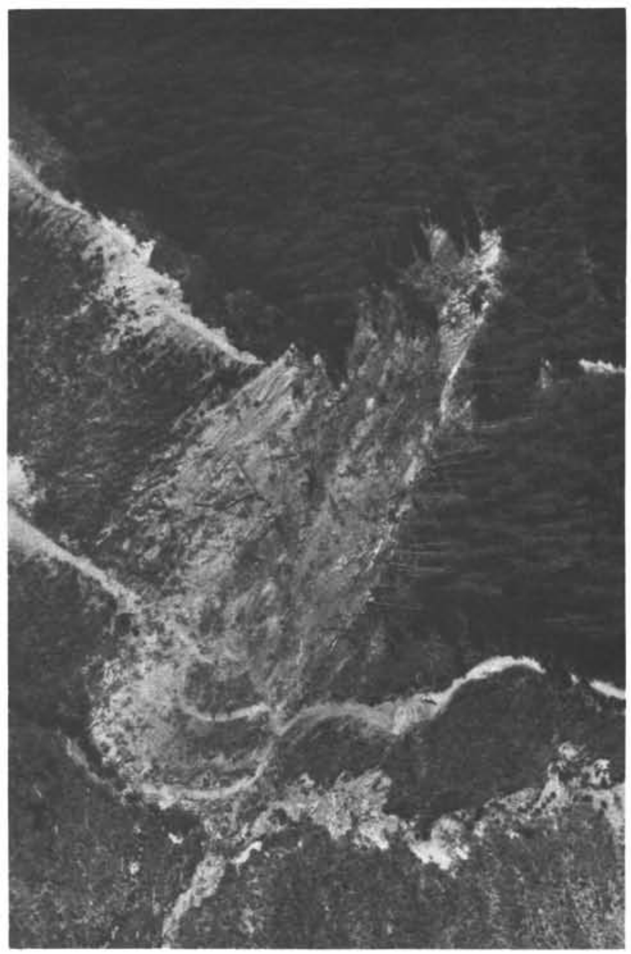


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Figure 5. Massive landslide near headwaters of Molalla River, tributary to Willamette River. Landslide occurred on lower slope during winter of 1973-1974, following building of two log-hauling dirt roads. Debris from toe of landslide has directly impacted stream channel. (Photo courtesy U.S. Geological Survey)

The completed erosion potential-sediment yield map of Oregon shows a good correlation between areas having a high sediment yield and areas dominated by soils and rocks having a high potential for erosion.

BASINWIDE ASSESSMENT

OBJECTIVES

The Oregon 208 Basinwide Assessment Project is concerned with procedures for relating stream quality to natural terrain characteristics and land management activities. Unlike the statewide assessment, which was concerned with identifying the existing effects of NPS pollution, this phase of the Assessment Project involves the development of a logical framework for determining the link between the causes of erosion (terrain-land management interactions) and the resultant stream-quality effects (Rickert and Beach, 1978). The map, matrices, and text have been designed specifically to minimize stream-quality impacts from problems associated with erosion and sedimentation.

THE PROBLEM

Erosion and sedimentation are naturally and continually occurring geologic processes that over long periods of time have reshaped the earth's surface. Erosion is the process by which soil and bedrock material are detached and transported, principally by water, wind, and gravity (Figure 5). Sedimentation results when eroded soil particles reach a drainage system and are carried downstream (Figure 6). Every stream has a unique capability to transport certain amounts of sediment. However, when sediment in a stream exceeds the amounts produced by natural erosion, the result is a form of man-caused pollution.

The effects of man-related erosion and sedimentation are dramatic and at times catastrophic. These processes deplete the soil resources of the land from which the sediment is derived, impair the quality of water in which it is transported, and reduce the productivity of lakes and estuaries where it is deposited. Sediment eliminates fish spawning and rearing areas, destroys insect larvae used by fish for food, shortens reservoir life, and affects the channel morphology of the transporting stream.

Sediment can also serve as an indicator of deficiencies in land and water management which allow sediment to reach the stream instead of remaining in the field, forest, range land, roads, or construction sites. Further, if soil is moving into a water course, other pollutants such as fertilizers, pesticides, salts, bacteria, and toxic metals, which often are attached to sediment, are also likely to be moving into the streams.

The problem is complex. Within any given basin in the State, many closely interrelated variables combine in varying degrees to cause NPS pollution of varying types and severities. The amount and spatial variation of sediment, for example, are strongly dependent upon the magnitude and characteristics of climatic events. In addition, close relationships exist between physical properties of the land surface (e.g., soils, geology, slope, runoff, and vegetal cover), geomorphological processes

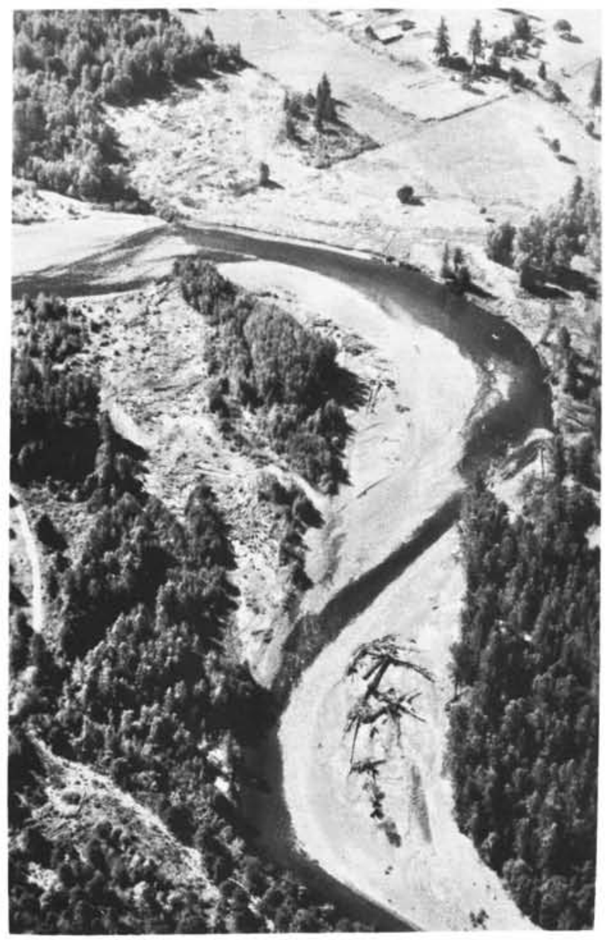


Figure 6. Stream-bed deposits in lower reach of Molalla River, near town of Molalla. As river enters flood plain, it begins to meander, shifting its channel and depositing sediment as sand and gravel bars. (Photo courtesy U.S. Geological Survey) →

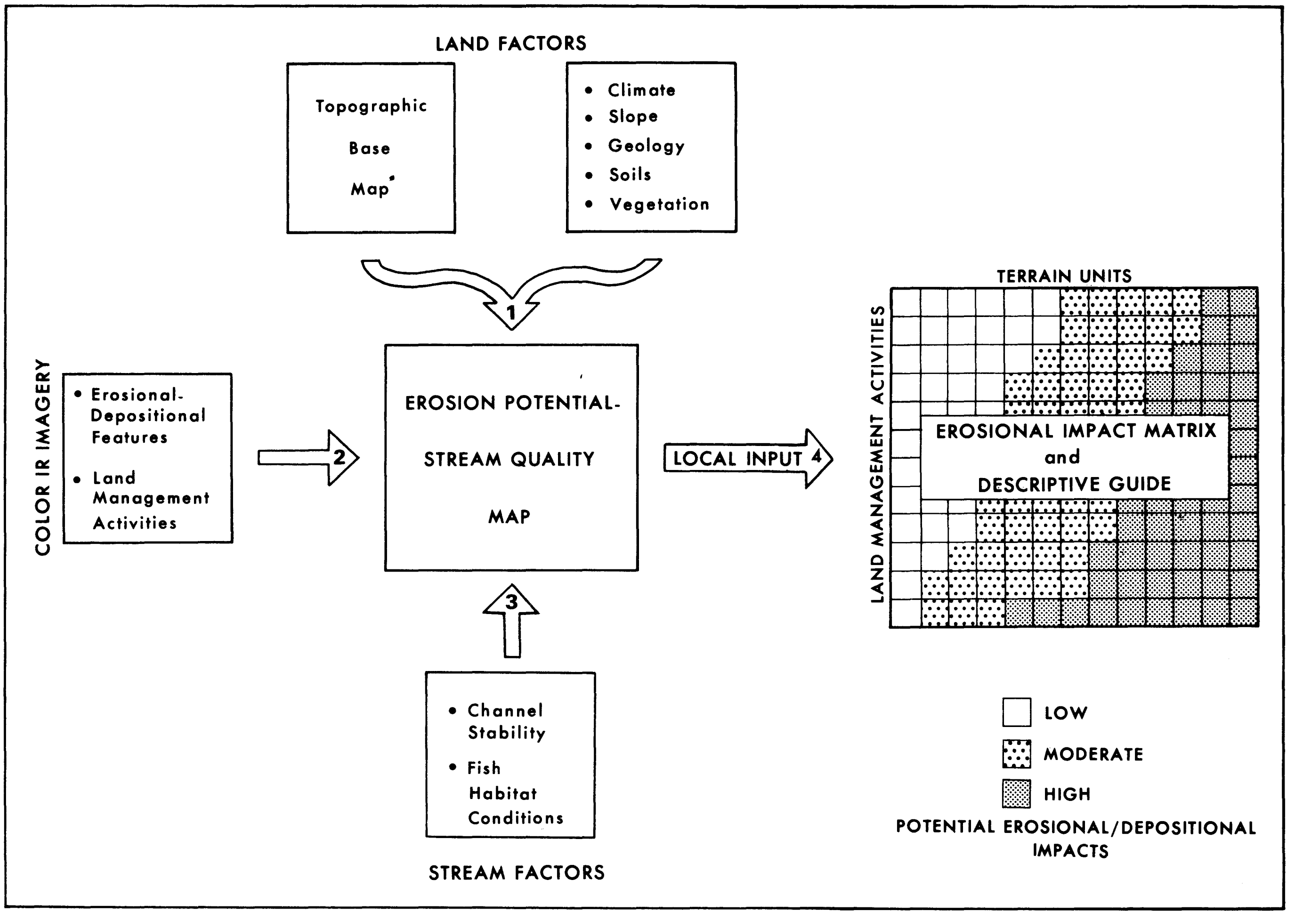


Figure 7. Oregon's process for determining suitability of rural land management activities. Process assesses relative erosional and sediment impacts on streams resulting from application of various land management activities on different types of terrain.

at work (e.g., rates of weathering, erosion, transport mechanisms, and deposition), and characteristics of land management activities (e.g., agriculture, grazing, forestry, mining, and urban/rural construction). The solution that addresses all of these environmental factors must also be systematic, reproducible, and readily usable by governmental agencies.

PROCEDURES

The basic procedure adopted for the basinwide assessment was initially developed by the U.S. Geological Survey (Rickert and others, 1976; Brown and others, 1979) and modified for Oregon's 208 Assessment Project. It consists of four steps (Figure 7) (Rickert and Beach, 1978; Rickert and others, 1978a).

Step 1

Information on climate, slope, geology, soils, natural vegetation, and generalized land use is collated. Only those factors that combine to explain the potential of the land to erode and that are compatible with the base-map scale (in this case 1:62,500) are selected for final analysis. See Brown and others, 1979, and Rickert and others, 1978a, for a complete discussion of this process.

Individual overlays of each important factor are prepared and composited to form an erosion-potential map that delineates distinctly different terrain types in the basin. These maps are useful because different terrains have different types and degrees of natural instability that must be recognized. For example, areas within a basin consisting of steep slopes, slide-prone bed rock, and poorly drained soils have a far greater erosion potential than do areas consisting of gentle slopes, competent bed rock, and well-drained soils (Figure 8). This kind of information must be systematically developed for all land in each basin to provide a sound basis for resource management.

Step 2

Land management activities are determined, and existing land and stream features caused by erosion and sedimentation are mapped. The various activities and pre-selected features are determined largely from color-infrared (IR) imagery; verification is made from published information, field and low-altitude aerial reconnaissance, and discussion with landowners and local agency personnel.

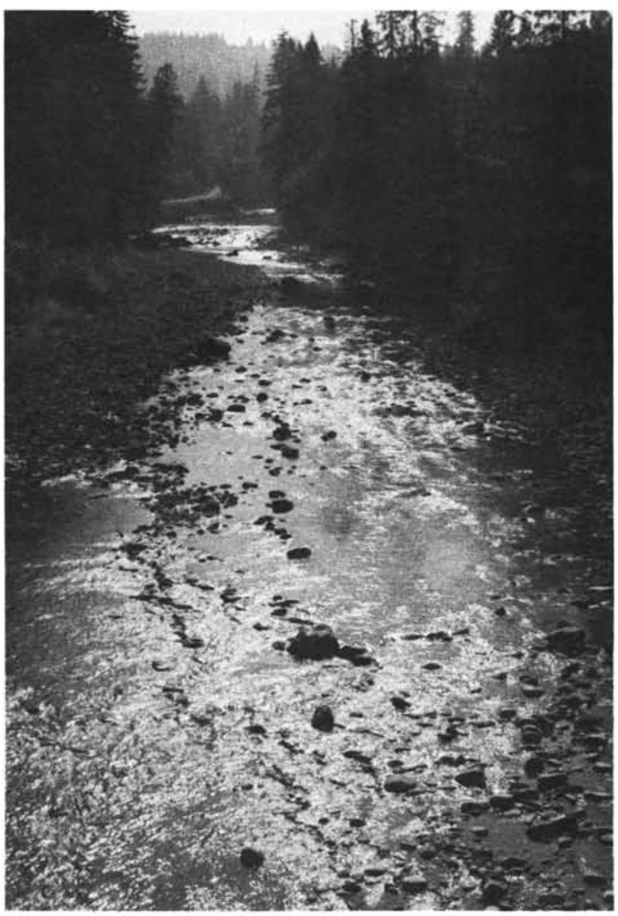
These erosion- and sedimentation-produced features are mapped to demonstrate relationships between the type and number of changes resulting from erosion, the natural potential of land to erode (as defined by the erosion-potential maps), and the type of management activities man imposes on the land.

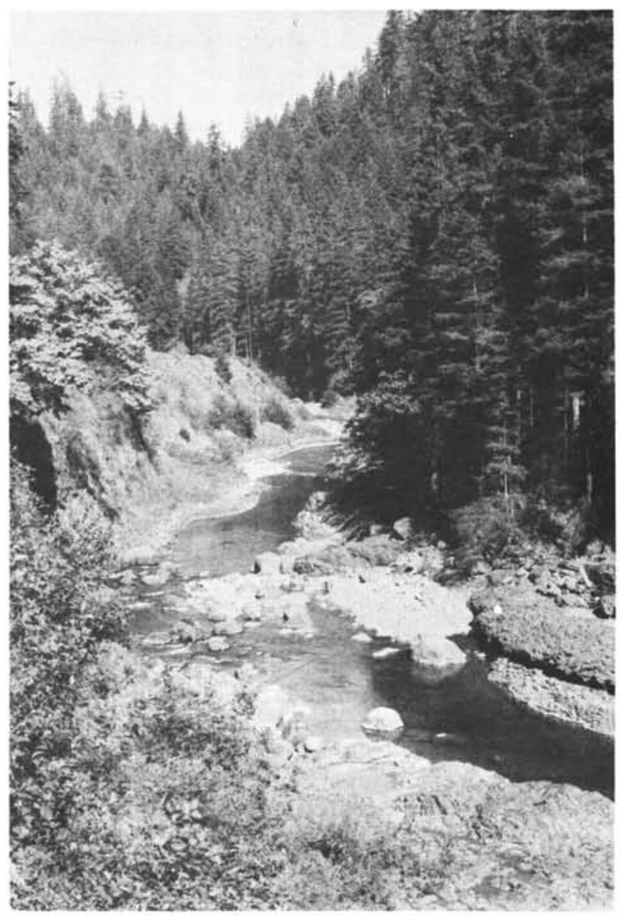
Step 3

Erosion-related stream-quality problems are assessed, using reconnaissance field surveys of channel stability and fish-habitat conditions. The channel-stability evaluation was modified from a stream survey developed by the U.S.D.A. Forest Service (1975); the fish condition evaluation was developed by biologists of the DEQ Assessment Team.

A variety of information, including location and type of fish occurrences; flow records used to determine the best time period for conducting the surveys; and assessments of land management activities, types of terrain, and types and uses of the

Figure 8. Examples of differences in channel morphology in Molalla River Basin. These two photos were taken within a few miles of each other. (Left) Molalla River, as it flows through easily eroded bed rock. (Right) Same river as it flows through more erosion-resistant basaltic rock.





streams, is needed to plan and conduct stream-quality surveys. Comprehensive survey forms are then used by the field teams as they walk selected segments of all major tributary streams within each study basin.

At the conclusion of field work, the collected data on channel stability, fish habitats, and, where there is intense stream-side management, riparian vegetation conditions are segregated into stream-quality ratings for each investigated segment. The results from these stream reconnaissance surveys are combined with information derived from air photo interpretation, terrain analysis of erosion-potential units, and land management activities to define impacts on streams from erosion/sedimentation-related nonpoint source pollution. For a detailed discussion of this stream-survey procedure, consult Rickert and others (1978a, Chapter V).

The results of these first three steps, depicted graphically on a regional map (scale 1:62,500), present a unique synoptic overview of (1) the erosion-potential units (terrain types), (2) all erosional-depositional features observable from the color IR imagery, and (3) the relative stream quality as determined from the field reconnaissance surveys. This completed map presents a dynamic picture of the land and stream processes within the identified basin. Because of its dynamic qualities, it can be used to predict where various types and magnitudes of erosional processes are likely to occur under varying conditions.

Step 4

The final and most important step is the development of a management tool for portraying the land and stream-quality effects of the various combinations of land erosion potentials and land management activities. The tool is a matrix (Figure 7) that lists the previously delineated terrain types on one axis and identified land management activities on the other.

Each terrain-activity combination is rated as having a high, medium, or low potential for erosion/sedimentation-related problems in nearby streams. The ratings are based on knowledge and experience of the assessment team, available and collected information, and input from a matrix committee of experts familiar with the basin. The matrix is utilized primarily for determining the regional suitability of various proposed activities or land uses of different types of terrain.

PRODUCTS

The maps and matrix are designed for both resource planning and management. For planning, they provide a screening mechanism for regional resource evaluation and suggest alternative activities for a given terrain unit that will minimize stream-quality degradation. For land management, the maps and matrix can be used to determine immediately areas where upgrading of land activities or application of conservation practices are necessary. In addition, they provide the basis for prioritizing site specific investigations of land management activities for critical terrain units.

SUMMARY

The concepts presented in this paper represent a significant step toward the development of a unified interpretive framework that can be used to control NPS and related problems in Oregon or throughout the nation. Emphasis has been placed on identifying existing stream- and water-quality problems and on establishing a means of analyzing the relationship between natural processes and man's activities on land and in streams.

STATEWIDE ASSESSMENT

In the statewide assessment phase of the project, the generalized locations of NPS pollution problems are identified. This geographical information will allow agencies to determine the distribution of problems that need investigation or remedial action. On a statewide or regional basis, the assessment provides information for prioritizing future programs for the study, remedy, and prevention of NPS pollution.

BASINWIDE ASSESSMENT

The basinwide assessment interrelates land management activities, the natural susceptibility of land to erode, and erosional effects on streams. The procedure can thus be used to (1) determine the suitability of various land management activities on different types of terrain, (2) monitor the success of land management guidelines and regulations, and (3) prioritize the need for site specific studies of land management activities.

Figure 9. Example of NASA high-altitude imagery of upper Molalla River Basin. By using stereo and high magnification, one can distinguish such erosional features as slump/earthflows, debris avalanches, talus, road failures, stream-bank failures, mining excavations, and large gullies; depositional features such as streambed deposits and debris jams; and various land management methods and practices. Lighter areas represent recent clear-cut harvesting, while darker areas show old-growth timber. (Photo courtesy National Aeronautics and Space Administration)

The procedure may also be used as a guide to the design of water-quality data-collection programs. In this context, the map and matrix show areas where erosional and depositional problems are most prevalent and where new problems are most likely to occur. Such areas will tend to be prominent sources of sediment. Thus, by using an erosion potential-stream quality map and impact matrix, data programs can be spatially designed to better define the cause-effect relationships of land and water quality.

ACKNOWLEDGMENTS

The author would like to acknowledge the many individuals and agencies who contributed to the development of this procedure. The project was directed by David A. Rickert, hydrologist, on loan to DEQ from the U.S. Geological Survey. The stream surveys were conducted by John E. Jackson and David M. Anderson, with assistance from James Sachet and Paul Krupin. Hank Hazen, a forester on loan from the U.S. Forest Service, helped coordinate agency cooperation and provided valuable information on land management activities. The talented cartographic skills of Elizabeth Suwijn greatly added to the graphic portrayal of the accumulated information.

In particular, John Beaulieu of the Oregon Department of Geology and Mineral Industries contributed on numerous occasions important new perspectives on the complex land-water processes and interrelationships. His many ideas and helpful suggestions can be found throughout the final report.

This project was financed in part with federal funds from the U.S. Environmental Protection Agency under grant identification number P-000110.

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Speculations on Oregon calderas, known and unknown

by John E. Allen, Professor Emeritus, Portland State University

Two spectacular calderas, Crater Lake and Newberry, have long been known and adequately mapped. One other, Harney Lake, has been suggested but not proven. Casual inspection of the ERTS photographs and the plastic relief maps of the 1:125,000 map series suggests that field work in relatively unstudied areas might prove the presence of several others. The following circular features appear to be particularly promising:

(1) The 4-mi-wide circular high basin with Bald Mountain, Wart Peak, and Wickiup Butte on its rim, located 9 mi south of Big Hole;
(2) The 3-mi-wide circular basin northeast of Yamsay Butte, 25 mi west of Summer Lake;
(3) The 6-mi-wide circular flat north of Diablo Mountain, 10 mi northeast of Summer Lake; and
(4) The 6-mi-plus-wide North Alkali Lakes basin, bounded on the east by a semicircular escarpment.

The payoff for an outrageous hypothesis is to find that it exhibits some regularity that permits one to extrapolate and predict (Allen and Beaulieu, 1976). The intervals between Crater Lake and the last three suggested calderas are very close to 35 mi; to Harney Caldera the interval is a bit longer. The circular features all lie on an almost straight east-west line which, if extended westward from Crater Lake, lies exactly on the Canyonville fault zone in the basement rocks mapped by Perttu (1976). The suggested Bald Mountain and Diablo calderas lie upon Lawrence's (1976) Eugene-Denio lineament. The intervals between Newberry Caldera and the suggested Bald Mountain and Yamsay Butte calderas are nearly 30 mi in a north-south line.

Nineteen years ago I suggested that there might be a volcano-tectonic graben beneath the High Cascades (Allen, 1965). Do you suppose that future field work will show more than three calderas in Oregon?

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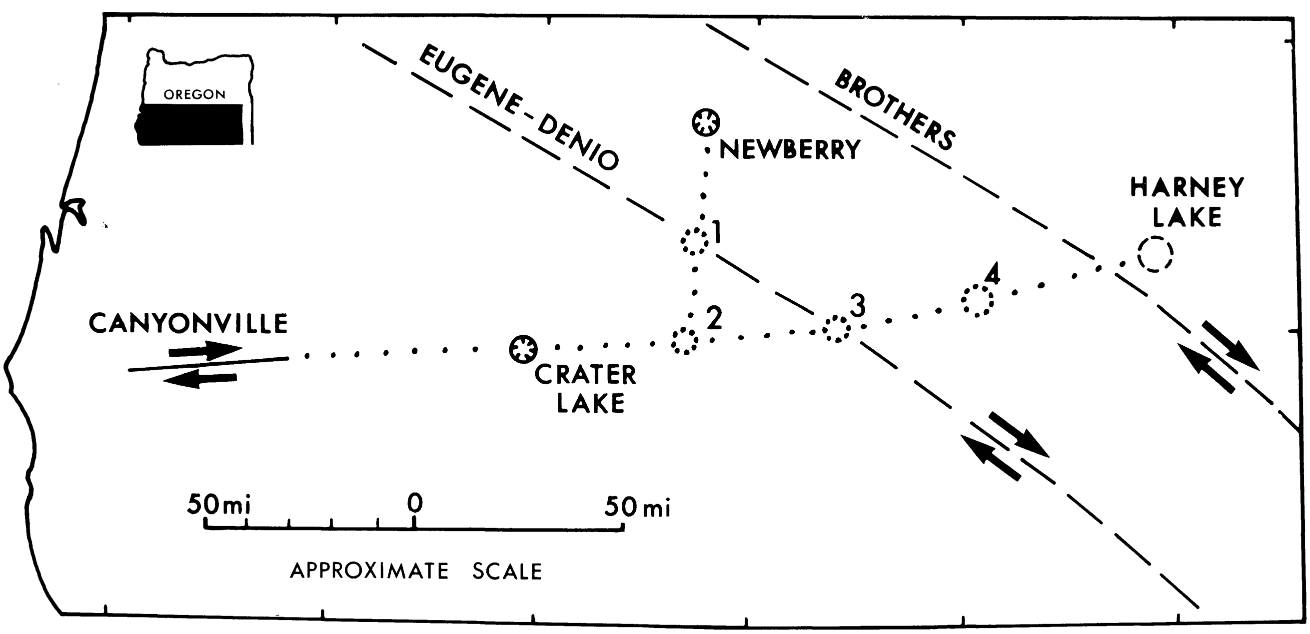
(see **CALDERAS** *, p. 32)*



meeting announcements

Each month, space permitting, upcoming meetings will be announced in this column. Information should reach our office no later than six weeks before a meeting. Please be specific and give full name of the organization; exact subject, location, and time of the meeting; and the name, address, and phone number of person to contact for questions or reservations.

AIME PLANS FEBRUARY MEETING

The Oregon section of the American Institute of Mining, Metallurgical, and Petroleum Engineers will meet Feb. 16, 1979, at the International Dunes Motel, at the Beltline exit of I-5 in Eugene. Len Ramp, Oregon Department of Geology and Mineral Industries, will speak on "Oregon Nickel Deposits." Ramp wrote the Department's recent publication, "Investigations of Nickel in Oregon."

Social hour is slated for 6:00 p.m.; dinner, 7:00 p.m.; speaker, 8:00 p.m. For additional program information, contact Rick Kent, 19443 Wilderness Drive, West Linn, Oregon 97068. His phone numbers are: (503) 243-4897 (days), and (503) 636-4146 (evenings). Reservations should be phoned or mailed to Vern Newton, Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201. Phone: (503) 229-5580.

ANNUAL OAS MEETING ANNOUNCED

The Oregon Academy of Science (OAS) will hold its annual meeting Feb. 24, 1979, at Mt. Hood Community College, in Gresham. In addition to the regular presentation of papers, there will be a symposium on geothermal energy in Oregon. Main speakers at the symposium will be Gordon Reistad, Associate Professor of Mechanical Engineering, Oregon State University, and Joseph Riccio, Geothermal Specialist, Oregon Department of Geology and Mineral Industries.

This meeting is open to the public. Persons wishing to eat lunch at the college should send reservations to Donald White, Department of Natural Sciences and Mathematics, Oregon College of Education, Monmouth, Oregon 97361. Tickets will be sold at the door. The approximate charge for the luncheon will be $2.00 to $2.50.

METALS AND MINERALS CONFERENCE SET FOR APRIL

The Pacific Northwest Metals and Minerals Conference, "Exploring '79," will convene at the Ridpath Hotel, Spokane, Washington. Dates for the conference are April 26-28. The conference will cover exploration, mining, metallurgy, and regulations. Forty-one presentations will be made. Chairman Thor Kiilsgaard said four field trips are scheduled during the conference.

For more information, contact Thor Kiilsgaard, AIME, American Society for Metals, 656 U.S. Court House, Spokane, Washington 99201. Phone: (509) 456-4677. □

USGS: Spotting the age of the Spotted Ridge Formation

The Spotted Ridge Formation occurs in a restricted area in east-central Oregon. It has been dated as Pennsylvanian and possibly Early Pennsylvanian on the basis of fossil plants. Marine fossils were recently obtained from conglomerate beds in the formation by Ewart Baldwin of the University of Oregon and have been studied by Mackenzie Gordon, Jr. This fauna includes the ammonoid genus *Cancelloceras*, which occurs in latest Namurian beds in northwest Europe. In the United States, this genus has been found elsewhere only in the upper part of the Hale Formation of northwest Arkansas. Deposition of the Spotted Ridge Formation during the late Hale (Early Pennsylvanian) is assured. □

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(**CALDERAS**, *from p. 31)*
Department of Geology and Mineral Industries, Ore Bin, v. 38, no. 6, p. 87-99.

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Waterfall alcoves in the Columbia Gorge

by John E. Allen, Professor Emeritus, Portland State University

I have not seen in print any explanation of the origin of the waterfalls in the Columbia River Gorge.

Nearly all of the higher falls lie in the centers of alcoves, cut back several hundred feet into the cliff faces that form much of the lower walls along the south side of the Gorge. These alcoves are generally from 150 to 300 ft wide, 10 to 40 times as wide as the falls themselves.

Waterfalls, like lakes, are ephemeral geological features, rarely lasting more than a few tens of thousands of years. Those in the Gorge must have been formed during or since the late Pleistocene by processes no longer active. It is not possible that a glacier ever occupied the Gorge to widen the normal V-shaped canyon, faceting the spurs between the tributary canyons to produce hanging valleys and waterfalls, as was the case in Yosemite Valley. No evidence indicates uplift of the south wall by faulting of the Gorge to produce the lower escarpments. Convincing evidence, however, has been found in recent years to substantiate Bretz' long-neglected Spokane or Missoula catastrophic flood*, along with indications of several such floods, at least one in pre-Wisconsin time. A six- to nine-hundred-ft-high flood, sweeping several times through the Gorge at speeds estimated to be over 30 mi per hour, could

*For an up-to-date bibliography, see Baker, V.R., and Nummedal, Dag, 1978, The channeled scabland, a guide to the geomorphology of the Columbia Basin, Washington, prepared for the Comparative Planetology Geology Field Conference, sponsored by the Planetary Geology Program, Office of Space Science, National Aeronautics and Space Administration, Washington, D.C. 20546.

Multnomah Falls, Columbia Gorge. (Photo courtesy Oregon Department of Transportation)

easily account for the lower near-vertical walls cut in the thick entablatures of massive brickbat jointed basalt flows which underlie most of the dozen or so highest waterfalls.

Waterfalls are almost lacking on the Washington side, due to the gentle south and southeastward dips in the Yakima Basalt, which have in most places brought the massive cliff-forming flows on the north side of the river high above flood levels. Any falls originally present would have been mostly destroyed by the extensive landslides which characterize so much of the Washington side of the river.

The alcoves in which the major falls lie could not have been formed by normal water erosion, by undercutting of the massive flows in less resistant interbeds, or by zones of weakness in the rocks.

I propose that the large alcoves resulted from the lateral spray from the falls seeping into the joint cracks during thousands of winter seasons, especially in the finely-spaced brickbat joints of the entablatures, and freezing and popping out the small blocks of basalt. Stream transport at the bases of the alcoves during spring freshets would remove the debris. The rate of alcove retreat, then, is a function of the number of freeze-thaw cycles since the original widening of the Gorge by the Missoula floods. Five hundred ft of retreat, as at Multnomah Falls, during the 13,000 years since the last catastrophic flood represents an average rate of a little over one-half in. per year. Oneonta Falls, 900 ft from the outer cliffs, retreated (along a weak fracture zone?) at nearly double this rate, perhaps so rapidly that an alcove did not have time to form. □

Mt. Hood geothermal research meeting held

Geoscience researchers engaged in the joint U.S. Geological Survey (USGS), U.S. Department of Energy (DOE), U.S. Forest Service (USFS), and Oregon Department of Geology and Mineral Industries (DOGAMI) project on the Geothermal Resource Assessment of Mt. Hood met in Portland on January 9-10, 1979. Fifteen individual research papers on various aspects of the assessment effort were informally presented. Discussion of the research followed the presentations.

From the USGS, D.L. Williams spoke on self-potential studies and remote sensing; H.D. Ackerman described refraction seismic studies; Jack Healy gave a presentation on reflection seismic studies; Guy Flanagan discussed aeromagnetic studies; Craig Weaver spoke on microseismicity; and J.H. Robison gave a paper on hydrology.

M.H. Beeson, Portland State University, detailed the stratigraphy and structure of the Columbia River Basalt Group in the Mt. Hood area. D.D. Blackwell, Southern Methodist University, talked on the heat flow modeling aspects of Mt. Hood Volcano. Results of the telluric-magnetotelluric survey of Mt. Hood were presented by N.F. Goldstein, Lawrence Berkeley Laboratory, and Edward Mozley, University of California.

The geochemistry of fumaroles and hot springs on Mt. Hood was the subject of a three-part presentation by H.A. Wollenberg, Lawrence Berkeley Laboratory; R.G. Bowen, consultant to DOGAMI; and J.H. Robison, USGS.

Craig White, University of Oregon, discussed the geology and geochemistry of young andesite lava flows on Mt. Hood. Richard Couch, Oregon State University (OSU), presented gravity data of Mt. Hood. Gunnar Bodvarsson, OSU, discussed the rheological aspects of the volcano. J.F. Riccio, DOGAMI, described the exploratory and heat-flow drilling recently completed in the Mt. Hood area. John Geyer explained the role of the USFS in the overall geothermal assessment.

State Geologist D.A. Hull chaired the meeting, and Hull and Williams presented opening and closing remarks.

Others attending the meeting included C.R. Bacon, USGS; J.C. Eichelberger, Los Alamos Scientific Laboratory, University of California; and Michael Korosec, Washington Department of Natural Resources.

Formal presentation of the papers may be given at an undetermined national meeting as part of a symposium on geothermal energy later this year or as a published effort in a geophysical or geological journal, probably as one complete monthly issue. □

J.F. Riccio, Geothermal Specialist
Oregon Dept. of Geology and Mineral Industries.

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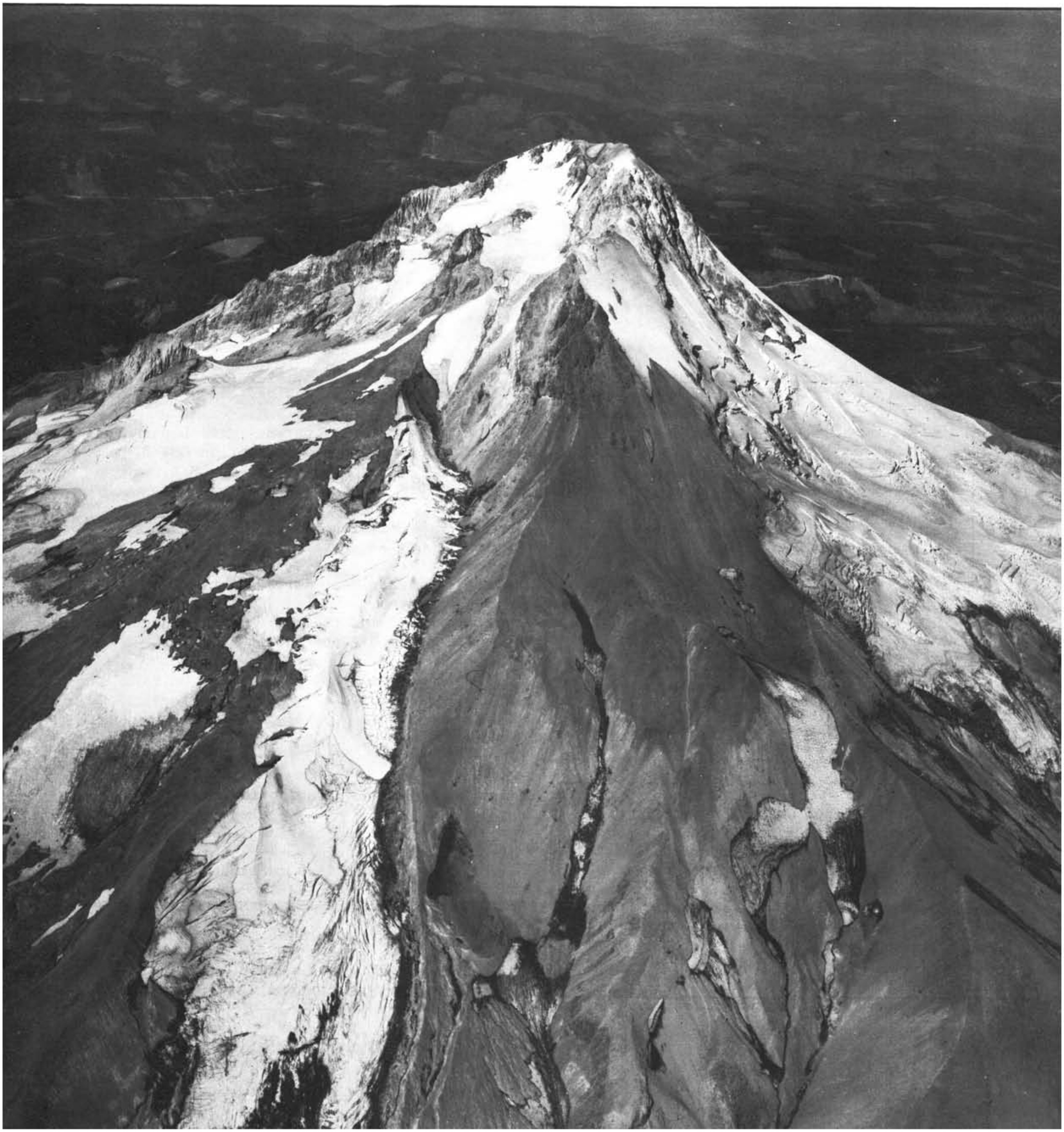

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COVER PHOTO

Mt. Hood, a High Cascade andesitic stratovolcano (elev. 11,235 ft (3,424 m)), located in Clackamas and Hood River Counties, was the focus of much geothermal exploration during 1978 (see article beginning p. 39). View is of the southeast side of the mountain. Crater Rock, a dacite plug dome with numerous active fumaroles, is just below the crest of the mountain. (Copyrighted photograph courtesy Delano Photographics, Inc.)

New Department publications

The Department, in cooperation with the Columbia Region Association of Governments (now the Metropolitan Service District), has produced Special Paper 3, "Rock Resources of Clackamas, Columbia, Multnomah, and Washington Counties."

Jerry Gray, Garwood Allen, and Gregory Mack wrote the comprehensive report, which presents data of value to land use planners and to potential users of rock resources.

The study covers 674 pits and quarries which have been or are being mined. Their locations are plotted on county highway maps scaled to one-half inch per mile. Tables listing past output and estimated potential are printed on the backs of maps.

The text forecasts future needs for rock resources in the four counties to the year 2000. If economic, population, and urban growth occur as predicted and no new sites are allowed to open or no material is allowed to be imported, all available resources could be used up by the year 2007.

Special Paper 3 can be purchased from the Department's Portland office for $7.00.

A gravity map prepared by the Department and OSU Oceanography Department is GMS-8, "Complete Bouguer Gravity Anomaly Map, Cascade Mountain Range, Central Oregon."

A detailed aeromagnetic map of the central part of the Western Cascades in Oregon is now available. GMS-9, "Total Field Aeromagnetic Anomaly Map, Cascade Range, Central Oregon," is the result of joint effort by the Department and the Oregon State University Oceanography Department.

Both maps, at $3.00 each, are on sale at the Portland, Baker, and Grants Pass offices.

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CONTENTS

Next month

Oregon's mineral industry in 1978

Geothermal exploration in Oregon in 1978

by J.F. Riccio, Geothermal Specialist, and V.C. Newton, Jr., Petroleum Engineer
Oregon Department of Geology and Mineral Industries

ABSTRACT

Government agencies and university researchers continued the geothermal research begun in 1977 on the Geothermal Resource Assessment of Mt. Hood Volcano. Northwest Natural Gas Co. completed its Old Maid Flat No. 1, begun in late 1977, on the western flank of the volcano.

Industrial exploration decreased, and no major discoveries were reported. The major effort by industry has been the drilling of temperature gradient holes to depths of less than 2,000 ft. The Department issued 16 permits for gradient holes deeper than 500 ft and 12 prospect well permits which encompassed a total of 117 shallow-gradient (less than 500-ft) holes.

INDUSTRY ACTIVITY

The most recent deep geothermal test in Oregon was the Klamath Hills well drilled by Thermal Power Co. in 1976. However, gradient drilling has increased annually for the past 5 years. Gradient holes were usually drilled to 200 or 300 ft, but experience has shown that deeper holes are needed to obtain better quality temperature data. Last year, therefore, exploration firms drilled most gradient holes to depths of 500 to 2,000 ft.

Figure 1. Areas of geothermal activity in 1978 in Oregon.

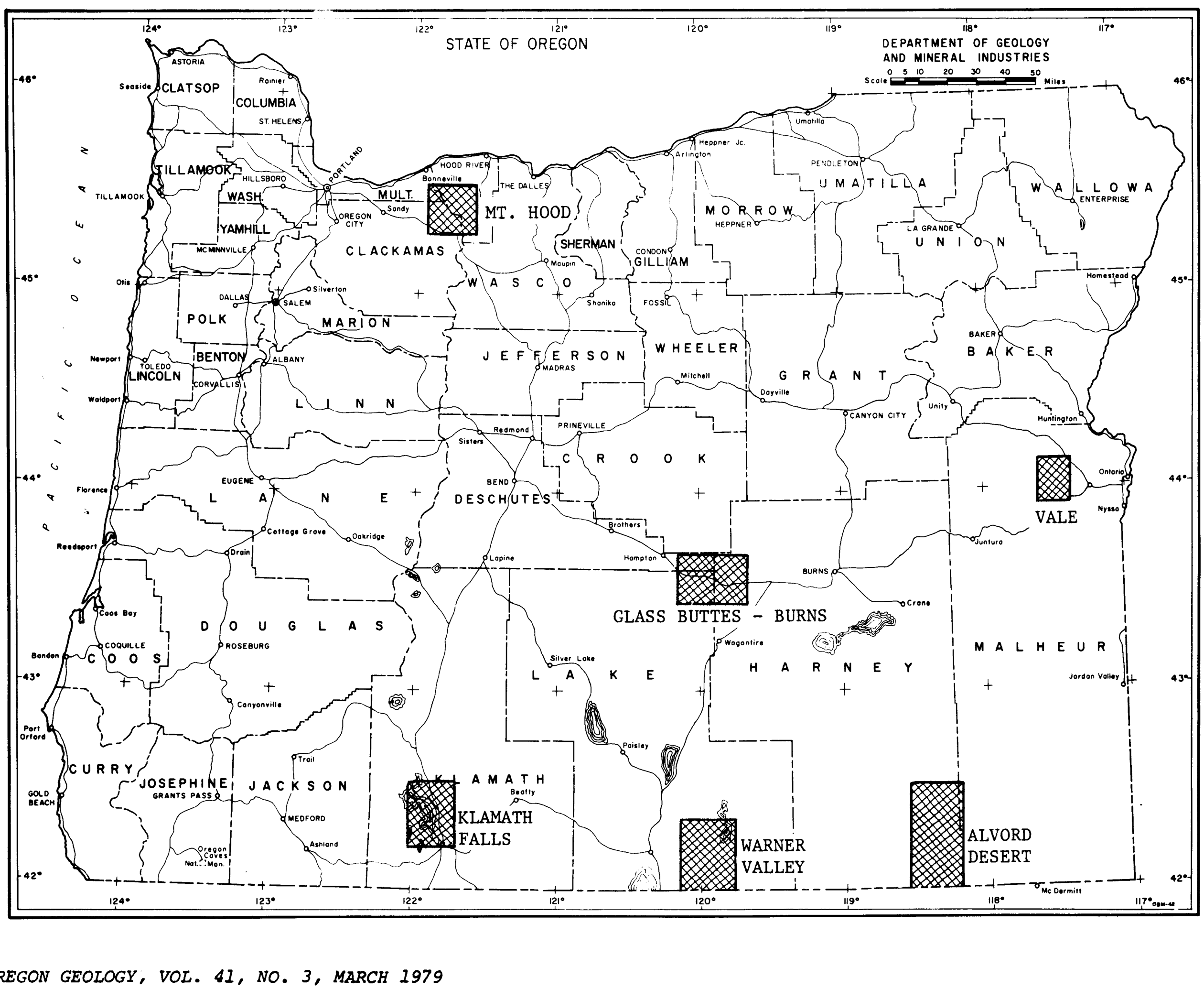


Table 1. 1978 State permits for geothermal wells

Permit no.	Company	Well name	Location	Depth drilled (ft)	Status
11	Northwest Natural Gas	Mt. Hood Old Maid Flat No. 1	SW¼ sec. 15 T. 2 S., R. 8 E. Clackamas Co.	4,003	Deepened from 1,850 to 4,003 ft; completed August 1978
20	Sunoco	Austin Hot Springs No. 1	NE¼ sec. 29 T. 6 S., R. 7 E. Clackamas Co.	1,484	Spudded December 1977; completed February 1978
32	Chevron Resources	Bully Creek Hole No. 5-1-78	SW¼ sec. 5 T. 18 S., R. 43 E. Malheur Co.	2,000	Monitoring temperature Nov. 11, 1978
33	Chevron Resources	Bully Creek Hole No. 9-1-78	NW¼ sec. 9 T. 18 S., R. 43 E. Malheur Co.	--	Drilling postponed until 1979
34	Wy'East Exploration	Timberline Hole No. 71-7	NE¼ sec. 7 T. 3 S., R. 9 E. Clackamas Co.	1,380	Work suspended Nov. 6
35	Anadarko Production	Alvord Valley Hole No. A-5	SE¼ sec. 6 T. 33 S., R. 36 E. Harney Co.	1,750	Completed Sept. 1978
36	Anadarko Production	Alvord Valley Hole No. A-6	SW¼ sec. 7 T. 33 S., R. 36 E. Harney Co.	1,994	Completed Oct. 1978
37	Anadarko Production	Alvord Valley Hole No. A-7	SW¼ sec. 18 T. 33 S., R. 36 E. Harney Co.	--	Drilling postponed
38	Anadarko Production	Alvord Valley Hole No. A-8	SE¼ sec. 14 T. 33 S., R. 35 E. Harney Co.	--	Do.
39	Anadarko Production	Alvord Valley Hole No. A-26	NE¼ sec. 29 T. 34 S., R. 34 E. Harney Co.	--	Do.
40	Anadarko Production	Alvord Valley Hole No. A-31	SW¼ sec. 34 T. 34 S., R. 34 E. Harney Co.	--	Do.
41	Anadarko Production	Alvord Valley Hole No. A-34	NE¼ sec. 8 T. 35 S., R. 34 E. Harney Co.	--	Do.
42	Anadarko Production	Alvord Valley Hole No. B-56	SE¼ sec. 10 T. 37 S., R. 33 E. Harney Co.	--	Do.
43	Anadarko Production	Alvord Valley Hole No. B-61	SW¼ sec. 13 T. 37 S., R. 33 E. Harney Co.	--	Do.

Table 1. 1978 State permits for geothermal wells (continued)

Permit no.	Company	Well name	Location	Depth drilled (ft)	Status
44	Anadarko Production	Alvord Valley Hole No. B-64	NW¼ sec. 22 T. 37 S., R. 33 E. Harney Co.	--	Drilling postponed
45	U.S. Geological Survey	Newberry Crater Hole No. 2	SW¼ sec. 31 T. 21 S., R. 13 E. Deschutes Co.	1,027	Drilling suspended Oct. 1978; will deepen to 2,000 ft or more in 1979
46	Ore-Ida Foods	Well No. 1	NE¼ sec. 3 T. 18 S., R. 47 E. Malheur Co.	--	Drilling to begin in April 1979; propose to drill to 8,000 ft
47	Ore-Ida Foods	Well No. 2	SE¼ sec. 3 T. 18 S., R. 47 E. Malheur Co.	--	To follow Well No. 1

According to present Oregon law, holes deeper than 500 ft are treated as production tests. The production holes listed in Table 1 were actually drilled for gradient information. The Department issued 17 geothermal well (deeper than 500 ft) permits (Table 1) and 12 prospect-well (shallow hole) permits (Table 2) in 1978. Prospect wells are granted under a blanket permit, and a total of 117 shallow gradient holes were drilled under the 12 permits (Figure 1).

Most of the known favorable geothermal areas have now been explored for gradient data. Additional deep production test holes are expected to be drilled within the next 2 or 3 years.

Leasing

Although acquisition of geothermal leases continued in 1978, the total acreage held may be somewhat less than in 1977. Gulf Oil reportedly relinquished more than half of its Oregon leases, and Thermal Power Co. turned back its leases in Klamath County in 1978. The relinquished acreage is believed to be larger than the 84,000 acres of new applications received by the U.S. Bureau of Land Management and the 7,000 acres of Known Geothermal Resource Area (KGRA) lands leased the past year.

Totals of federal and State leases in Oregon are shown in Table 3. The acreage noted for the private leases is an estimate inasmuch as confirmation is difficult.

U.S. Bureau of Land Management 1978 KGRA lease sales are shown in Table 4. The only lease sales activity was by SUNOCO Energy in the Breitenbush Hot Springs area. Tentative schedule for U.S. Bureau of Land Management KGRA lease sales for 1979-80 is given in Table 5.

Old Maid Flat No. 1, Clackamas County

The geothermal exploratory test hole, Old Maid Flat No. 1, located in the SE¼SW¼ sec. 15, T. 2 S., R. 8 E., at an elevation of 2,750 ft, was completed in midsummer 1978 at a depth of 4,003 ft (Figure 2). Specifically, the exploratory hole was drilled adjacent to the Sandy River, on the westerly flank of Mt. Hood.

This test originally began in October 1977 and was suspended at 1,850 ft because of mechanical problems in early December 1977. In late July 1978, a small, 4,500-ft-capacity oil rig was used to re-enter the hole. The existing hole, 7-7/8-in. in diameter, was carried to a total depth of 4,003 ft with bentonite mud. The U.S. Department of Energy and Northwest Geothermal Corp.,

Table 2. 1978 State permits for prospect wells

Permit no.	Company	Issue date	Area of work	Comments and status
36	Aminoil	March 1978	Alvord Valley and Glass Buttes, Harney and Lake Cos.	Drilled five 500-ft gradient holes at Alvord Valley and four 500-ft gradient holes at Glass Buttes
37	Aminoil	March 1978	Breitenbush, Marion Co.	Project canceled
38	Phillips Petroleum	May 1978	Brothers Fault Zone, Lake and Harney Cos.	Completed drilling 44 500-ft gradient holes in Oct. 1978
39	Union Oil	June 1978	Mickey Hot Springs, Harney Co.	Completed drilling seven 250-ft gradient holes in July 1978
40	Hunt Energy	July 1978	South Warner Valley, Lake Co.	Completed drilling 12 200-500-ft gradient holes in Sept. 1978
41	Hunt Energy	--	Owyhee Reservoir, Malheur Co.	Project postponed
42	Hunt Energy	July 1978	Klamath Falls, Klamath Co.	Completed drilling 11 500-ft gradient holes in July 1978
43	Chevron Resources	July 1978	Bully Creek, Malheur Co.	Completed drilling five 500-ft gradient holes in Sept. 1978
44	Anadarko Production	Aug. 1978	Alvord Desert, Harney Co.	Completed drilling 21 500-ft gradient holes in Oct. 1978
45	Dept. of Geology and Mineral Industries	Sept. 1978	Mt. Hood, Clackamas, and Hood River Cos.	Completed drilling 11 500-ft gradient holes in Dec. 1978
46	John Hook	Oct. 1978	Sisi Butte, Clackamas Co.	Project postponed
47	Northwest Natural Gas	Nov. 1978	Old Maid Flat No. 2, Clackamas Co.	Drilled Clear Fork gradient hole to 500 ft; approval granted to deepen hole; deepened to 1,320 ft

Table 3. Geothermal leases

Type of leases	Number	Acres
Federal		
Noncompetitive	107 USBLM*	147,333
	10 USFS**	22,337
KGRA	30 USBLM*	60,685
	4 USFS**	5,818
Applications pending		83,460
	Total	319,633
State		
Leases active in 1978		8,294
Applications pending		None
Private		
Leases active in 1978		180,000

*U.S. Bureau of Land Management
**U.S. Forest Service

a subsidiary of Northwest Natural Gas Co., supplied funds for deepening the hole. The drilling contractor was Taylor Drilling Co. of Chehalis, Washington.

A complete set of geophysical logs, including temperature gradient data, for this hole is available from the Oregon Department of Geology and Mineral Industries as Open-File Report 0-78-6.

Ore-Ida Foods, Inc.

In late 1978, Ore-Ida Foods, Inc., and the U.S. Department of Energy agreed to a 3-year cost-sharing demonstration

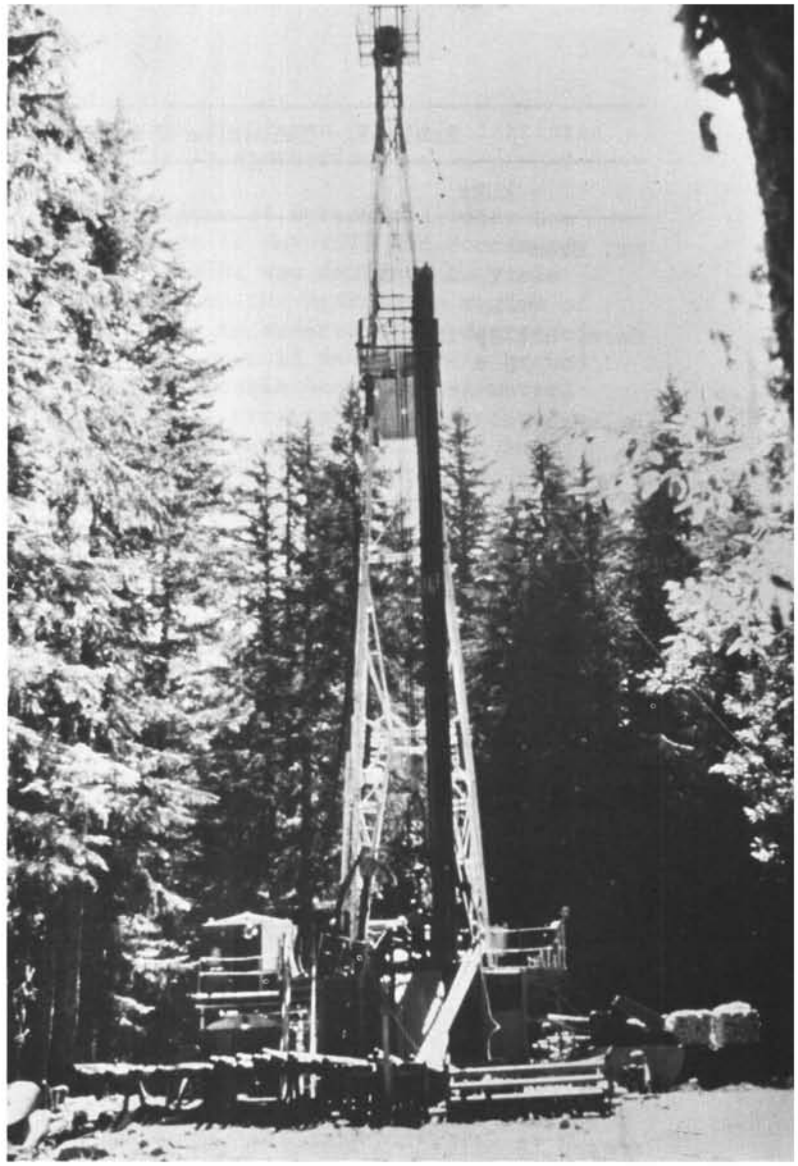


Figure 2. Old Maid Flat No. 1, Clackamas County.

Table 4. 1978 U.S. Bureau of Land Management KGRA lease sales

Tract no.	Date	Company	Area	Acreage	Bid/acre
* 1-13	July 27	--	Crump Geyser	22,756	No bids
*14-18	July 27	--	Klamath Falls	1,366	Do.
*19-29	July 27	--	Burns Butte	4,228	Do.
1	Oct. 19	Sunoco Energy	Breitenbush Hot Springs	2,133	$13.00
2	Oct. 19	Sunoco Energy	Breitenbush Hot Springs	1,280	$17.65
3	Oct. 19	Sunoco Energy	Breitenbush Hot Springs	1,365	$23.78
4	Oct. 19	Sunoco Energy	Breitenbush Hot Springs	1,040	$ 3.65
5	Oct. 19	--	Breitenbush Hot Springs	1,029	No bids

*These tracts were re-offered because no bids were received for them in previous sales

Table 5. Tentative U.S. Bureau of Land Management sales dates

KGRA	Date of sale	Location
Mt. Hood	Jan. 15, 1979	T. 2 S., R. 9 E. Hood River and Clackamas Cos.
Carey Hot Springs	Feb. 13, 1979	T. 6 S., R. 6-7 E. Clackamas Co.
Belknap Hot Springs	Sept. 27, 1979	T. 16 S., R. 6 E. Lane Co.
McCredie Hot Springs	Oct. 23, 1980	T. 21-22 S., R. 4-5 E. Lane Co.
Newberry Caldera	Dec. 1980	T. 21-22 S., R. 12-13 E. Deschutes Co.
Alvord	No date set	T. 32-37 S., R. 33-36 E. Harney Co.

program to find and utilize geothermal energy which will be used to substitute a portion of the Ore-Ida food processing plant's energy requirements at Ontario, Oregon. Drilling of the initial well on Ore-Ida property (Figure 3) will begin in April 1979 if drilling equipment is available.

RESEARCH

Basic and applied geothermal research is being conducted in the State by several universities, the U.S. Geological Survey, and the Department of Geology and Mineral Industries. Recent Department geothermal papers include *Heat Flow of Oregon* (Special Paper 4) (in preparation), *Low- to Intermediate-Temperature Thermal Springs and Wells in Oregon* (Geological Map Series 10) (in press), *Geothermal Gradient Data* (Open-File Report O-87-4), and *Geophysical Logs, Old Maid Flat No. 1, Clackamas County, Oregon* (Open-File Report O-78-6).

Figure 3. Aerial view of Ore-Ida's food processing plant at Ontario, Malheur County, showing site of proposed geothermal well. (Photo courtesy Ore-Ida Foods, Inc.)

Mt. Hood geothermal resource assessment

In February 1977, the U.S. Department of Energy, U.S. Geological Survey, U.S. Forest Service, and the Department jointly undertook a geothermal energy resource assessment of Mt. Hood Volcano in the northern Oregon Cascade Range. This assessment continued throughout 1978 and will culminate in 1979 in the publication of final reports by the respective researchers. Some of the Department-administered field studies have been managed by staff personnel and/or consultants; other phases have been conducted by university researchers working under subcontract to the Department as noted below.

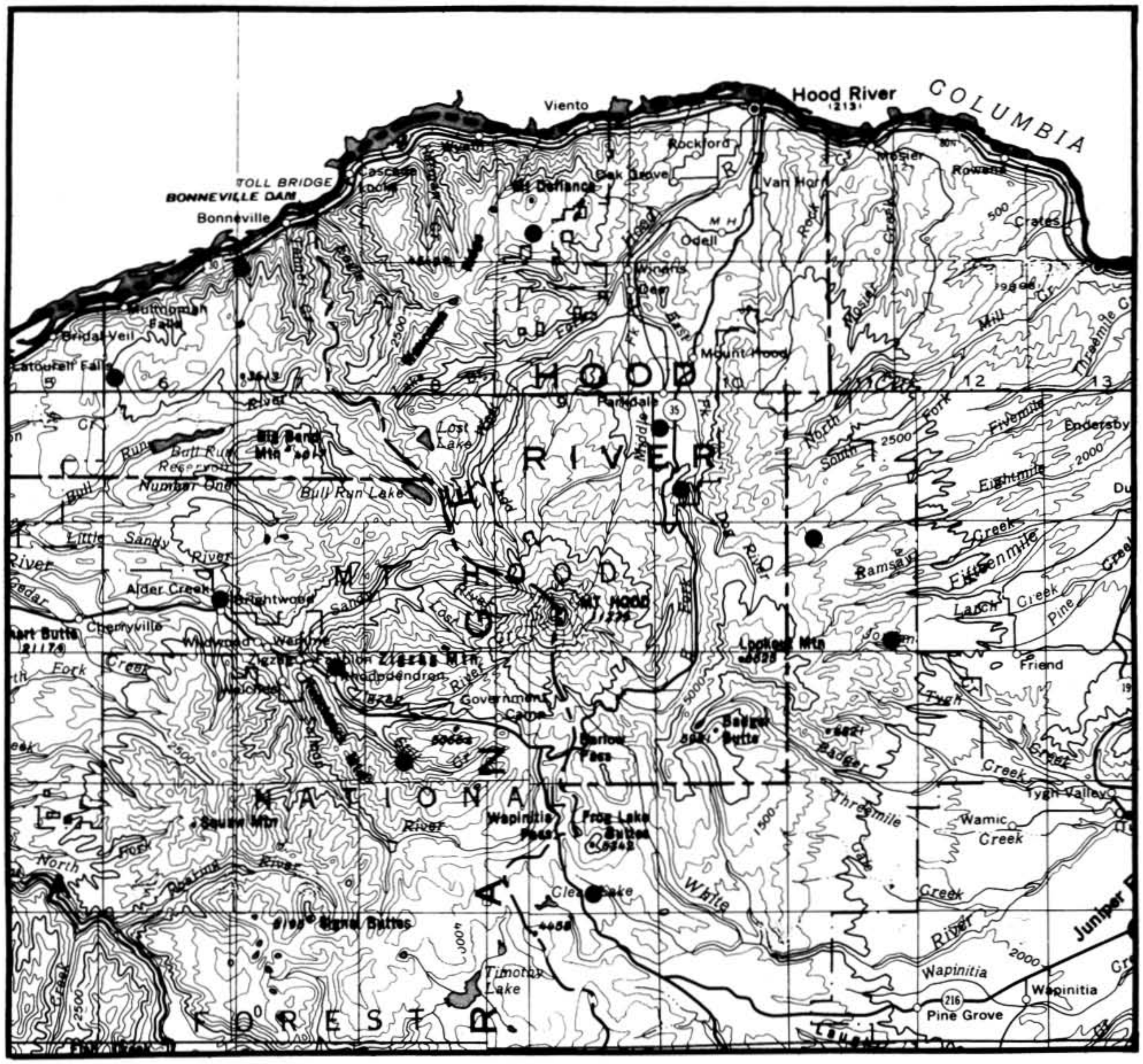
Geologic studies of the volcano are being jointly conducted by C.M. White, Department of Geology, University of Oregon, and D.A. Hull, Department of Geology and Mineral Industries. Rock geochemistry and magnetic polarity of the young andesite flows are also being investigated by White.

The Geophysics Group, under the direction of R. Couch and K. Keeling, Oregon State University, obtained gravity measurements for 239 stations in the Mt. Hood area. A free-air gravity map of Mt. Hood, based on the station data, has been completed and will be published soon. A complete bouguer gravity anomaly map of Mt. Hood will be published in 1979.

Thermal modeling of the Mt. Hood Volcano area has been undertaken by D.D. Blackwell, Southern Methodist University. Preliminary interpretation of the regional heat flow and geothermal gradient data in the northern portion of the Cascades Range in Oregon has been initiated and partially synthesized.

A program of systematic water sampling, begun in May 1977 and continued into late 1978, was designed to yield information on the hydrologic regime of Mt. Hood and to ascertain the degree of mixing between cold near-surface ground water and probable deep thermal water. Water samples were taken from cold springs, cold surface drainages, Swim Warm Springs, and condensate from the fumaroles at Crater Rock on Mt. Hood. The study was a joint effort by H.A. Wollenburg, Lawrence Berkeley Laboratory; J.H. Robison, U.S. Geological Survey;

Figure 4. Location of temperature gradient holes, Mt. Hood area, Multnomah, Hood River, Clackamas, and Wasco Counties. Scale - 1:500,000.



and R.G. Bowen, consultant to the Department of Geology and Mineral Industries.

A study of the stratigraphy and structure of the Columbia River Basalt Group in the northern Oregon Cascade Range with particular emphasis on the Mt. Hood area has been undertaken by M.H. Beeson, Portland State University. The Department expects to publish the results of this study in mid-1979.

G. Bodvarsson, Oregon State University, and A. Johnson, Portland State University, are determining the rheological aspects of the Mt. Hood Volcano as they apply to the detection and delineation of volcanic geothermal resources, in particular those connected with subsurface molten or quasimolten plutons.

Statewide low- to intermediate-temperature resource inventory

In addition to the Mt. Hood project, the Department has been engaged in a statewide inventory of low- to intermediate-temperature geothermal resources. The initial phase, completed in 1977, was a compilation of published and unpublished chemical data on thermal springs and water wells for inclusion in the U.S. Geological Survey computer-based GEOTHERM program. In 1978, thermal springs and wells not previously sampled were sampled and water analyses were determined for inclusion in the GEOTHERM program. These data appeared and were utilized in USGS Circular 790. As a result of this research, the Department has also published Geologic Map Series 10, which contains specific locations and data on thermal springs and wells in Oregon.

Figure 5. Thermal gradient drilling by Oregon Department of Geology and Mineral Industries near Clear Lake, Wasco County, November, 1978.

Temperature-gradient drilling

In late December 1978, the Department completed the last of 11 heat flow holes in the Mt. Hood area (Figures 4 and 5) to depths ranging from 250 to 500 ft. These holes are so equipped that temperature gradients can be measured. Data obtained will be synthesized and published as an open-file report in the near future.

Other Department research

During 1978 the Department compiled a preliminary geothermal resource map of Oregon which should be ready for publication and distribution in mid-1979.

U.S. Geological Survey research

As part of the Mt. Hood Assessment Program, the U.S. Geological Survey has completed aeromagnetic and seismic studies related to the geothermal potential of the volcano. Infrared and side-looking airborne radar (SLAR) remote sensing studies will continue into 1979.

Lawrence Berkeley Laboratory

Lawrence Berkeley Laboratory was responsible for the magnetotelluric study done at Mt. Hood. A telluric-magnetotelluric (T-MT) survey was utilized as the electrical resistivity technique, and the results were published in June 1978 as LBL-750.

Other research

The Department and GEO-Heat Utilization Center at OIT completed a study of the Agribusiness geothermal energy utilization potential of Klamath and western Snake River Basins, Oregon, under a U.S. Department of Energy contract. This study was published in March 1978 by OIT.

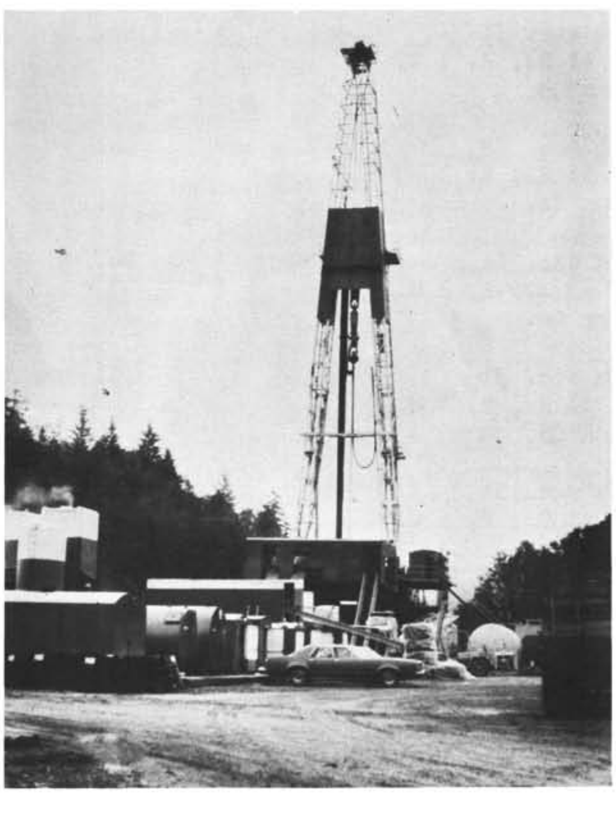
The Eastern Oregon Community Development Council at La Grande published its study on the Northeast Oregon Geothermal Project. This report, done under the direction of Rich Huggins, presents an inventory and analysis of available geologic data and a discussion of the economic, institutional, and environmental issues involved in geothermal development for Baker and Union Counties.□

Oil and gas exploration in Oregon in 1978

by V.C. Newton, Jr., Petroleum Engineer
Oregon Department of Geology and Mineral Industries

There was more oil and gas activity during 1978 than in any other of the 76 years of oil and gas exploration in Oregon. The Department issued 11 drilling permits, and work continued on a twelfth permit. For many states, this would not be an impressive level of activity, but considering that Oregon is a frontier area where no production has yet begun, it signals a new round of exploration.

Mobil's Sutherlin Unit No. 1, a very significant exploration wildcat, is underway in northwestern Douglas County (Figure 1). Spudded in lower marine rocks, the test hole should penetrate into Mesozoic rocks when drilled to the proposed depth of 14,000 ft. The company reportedly expects to discover natural gas at the site. Mobil's drilling in Douglas County was preceded by at least 5 years of geological and geophysical studies. Mobil's leased acreage is one of the largest blocks assembled in the State. It is said to comprise one million acres.



← Figure 1. Mobil's Sutherlin Unit No. 1, near Oakland, Douglas County. If drilled to proposed depth of 14,000 ft, this will be deepest hole ever put down in Oregon.

A second major development has been taking place in northwestern Oregon and southwestern Washington, where Floyd Cardinal, independent from Billings, Montana, has accumulated approximately 400,000 acres of leases. He has applied for 125,000 acres of Oregon state-owned leases, including some in the bed of the Columbia River. In 1978, Cardinal also leased 77,000 acres of state-owned leases, much of which is submerged land, in southwestern Washington. In 1971, the discovery in Clatsop County of what appears to be Oregon's first natural oil seep of significant size revived interest in that region.

Reichhold Energy and its partner, Diamond Shamrock Corp., put down a seventh test hole in Columbia County in 1978 (Figure 2). Northwest Natural Gas Co. participated in drilling the first four holes in 1975. The group is currently looking for a gas discovery in northwestern Oregon.

The Reichhold group is estimated to be holding 100,000 acres, fourth in size of acreage blocks leased for oil and gas in the State. Texaco holds more than 200,000 acres of leases in central Oregon but has done no drilling there since 1971.

Chevron U.S.A., Inc., did hold approximately 200,000 acres of leases in eastern Oregon at the end of 1977 but is reported to have relinquished a large portion of this land. Michel Halbouty, a Texas independent, drilled a 7,600-ft wildcat as a farmout on Chevron leases in 1977 (see Figure 3).

A total of 2 million or more acres of onshore oil and gas leases are estimated to have been in effect in 1978, an all-time high for Oregon. The fol-

Table 1. 1979 Oil and gas permits

Permit no.	Company	Well name	Location	Total depth (ft)	Status
71	Reichhold Energy	DSC - Columbia County No. 2	NE¼ sec. 14 T. 6 N., R. 5 W. Columbia Co.	2,780	Suspended July 18, 1978
74	John Rex Agoil of Oregon	Grizzly No. 1	SE¼ sec. 33 T. 12 S., R. 15 E. Jefferson Co.	3,300	Suspended in Sept. 1978
75	Mobil Oil Corp.	Sutherlin Unit No. 1	SW¼ sec. 36 T. 24 S., R. 5 W. Douglas Co.	9,000	Drilling; projected depth 14,000 ft
76	Agoil of Oregon	Hay Creek Ranch No. 1	NE¼ sec. 23 T. 11 S., R. 15 E. Jefferson Co.	--	Plan to drill early in 1979
77	Agoil of Oregon	Hay Creek Ranch No. 2	NW¼ sec. 6 T. 11 S., R. 15 E. Jefferson Co.	--	Do.
78	Farnham Chemical	Smith No. 1	NW¼ sec. 32 T. 11 S., R. 1 W. Linn Co.	--	Do.
79	Farnham Chemical	K. Barr No. 1	NE¼ sec. 31 T. 11 S., R. 1 W. Linn Co.	--	Location approved by county
80	Farnham Chemical	Normac No. 1	NE¼ sec. 31 T. 11 S., R. 1 W. Linn Co.	--	Do.
81	Mobil Oil Corp.	Ira Baker No. 1	NE¼ sec. 28 T. 15 S., R. 3 W. Linn Co.	--	Do.
82	Mobil Oil Corp.	Ernest Glaser No. 1	SW¼ sec. 14 T. 13 S., R. 3 W. Linn Co.	--	Do.
83	Farnham Chemical	Normac No. 2	NW¼ sec. 31 T. 11 S., R. 1 W. Linn Co.	--	Do.
84	Farnham Chemical	Normac No. 3	NW¼ sec. 31 T. 11 S., R. 1 W. Linn Co.	--	Do.

lowing firms held leases in Oregon in 1978 (see Figure 3):

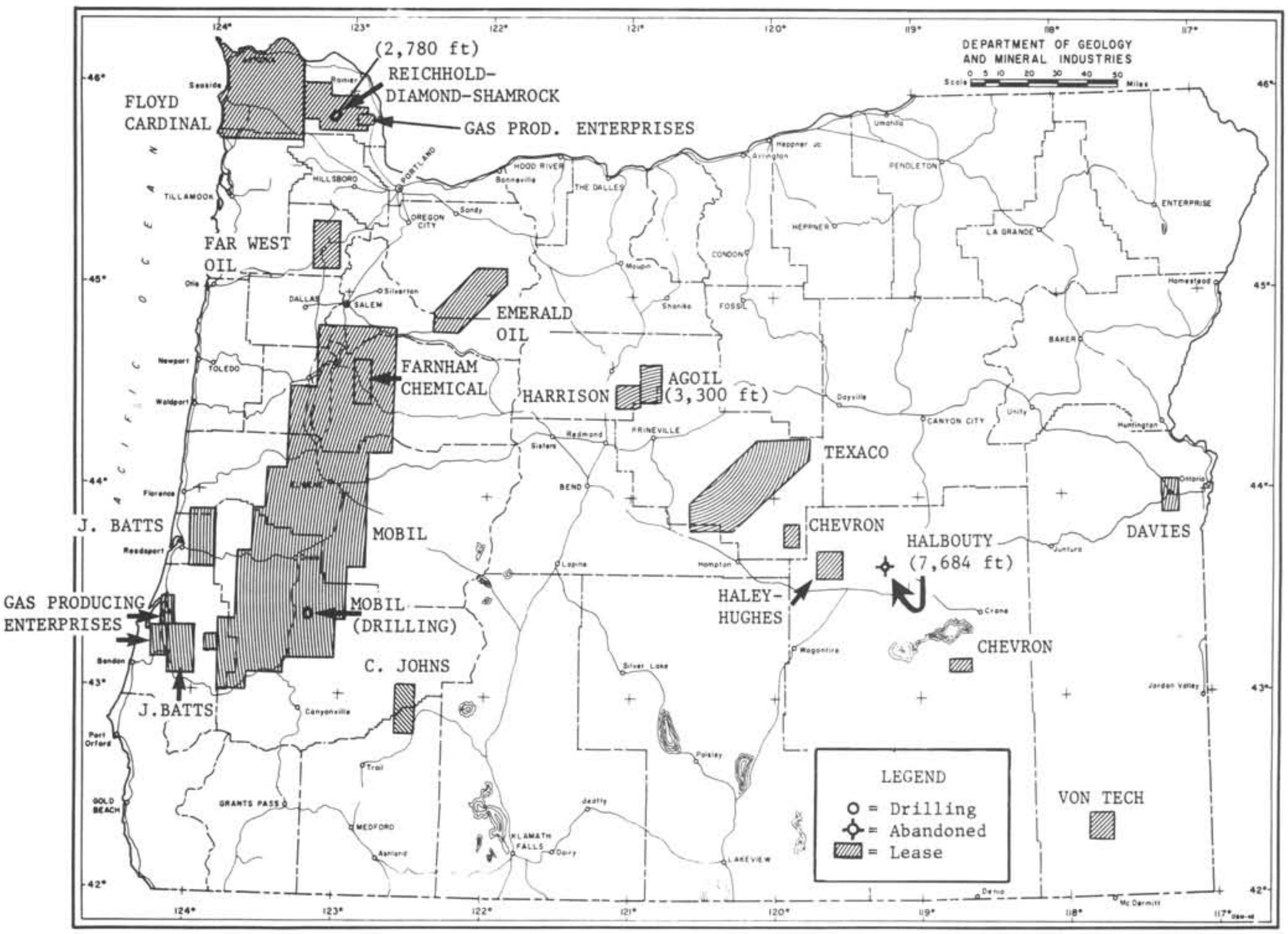
Mobil Oil Corp., Denver, Colo.
Floyd Cardinal, Billings, Mont.
Texaco, Inc., Los Angeles, Calif.
Chevron U.S.A., Inc., San Francisco, Calif.
Reichhold Energy Corp., Tacoma, Wash.
Northwest Exploration Co., Denver, Colo.
Gas Producing Enterprises, Denver, Colo.
Agoil of Oregon, Portland, Oreg.
Farnham Chemical, Portland, Oreg.
Robert Harrison, Seattle, Wash.
Emerald Oil, Salt Lake City, Utah
Ericc Von Tech, North Bend, Oreg.
Far West Exploration-Pacific States Oil, Portland, Oreg.
John Batts, Billings, Mont.
Haley-Hughes, Denver, Colo.

The State Land Division adopted a competitive bidding system for State lands in November 1978. Prior to adoption of this rule State leases were given as applications were submitted.

Judging from the number of leases outstanding and the number of drilling permits issued last year, 1979 should prove to be a very eventful year in Oregon for petroleum exploration.□

Figure 2. Reichold-Diamond Shamrock's vibrating seismic truck, operating June 1978 in Columbia County.

Figure 3. Oil and gas leases and wildcat wells in Oregon in 1978.



Oregon's mined land reclamation in 1978

by Standley L. Ausmus, Administrator, Mined Land Reclamation Division
Oregon Department of Geology and Mineral Industries

The reclamation of surface mined land in Oregon continues to involve principally the sand, gravel, and stone producers, who represent Oregon's major mining activity. The success of the program is measured chiefly in terms of the number of ongoing and completed reclamation projects; but, to a large extent, the true impact should be measured more in terms of public awareness and operator cooperation. In this regard, the industry and its representatives are, for the most part, doing an excellent job of reclaiming their sites, often going beyond that which is specifically required.

The requirements for surface mining reclamation in Oregon are summarized below.

1. All surface mining activity which exceeds 2,500 cu yd or 1 acre per year is subject to some provisions of the State law.
2. Reclamation and bonding requirements apply only to surface mined land affected after July 1, 1972.
3. Initial application, good for one year, costs $265.00. Annual renewal is $165.00. There are no other fees.
4. Amount of the bond is determined by the Department but is limited to the statutory maximum.
5. The reclamation must be completed within 3 years following completion of mining.
6. The reclamation project and plan must be approved by the Department and is subject to review by other agencies and jurisdictions.

It should be pointed out that there is no statutory requirement for restoration of any mining site to its original contours. This concept is not applicable to most of the mining conducted in Oregon.

REVIEW OF 1978

During calendar year 1978, 49 new mining permits with approved reclamation plans were issued, and another 235 were renewed. During the same time period, 40 new permits were issued to "grandfathered" sites, and 252 were renewed. The total number of permits processed was 576; another 446 applications for certificate of exemption were processed. Total applications of all classifications processed during 1978 was 1,022.

Table 1. Comparison of 1977 and 1978 Mined Land Reclamation activities

	1977	1978
Operating permits		
New	50	49
Completed	7	6
In effect at year's end	246	292
Grandfather permits		
New	37	40
Completed or converted to full permit	21	33
In effect at year's end	220	332
Net increase (fee sites)	53	58
Average increase (fee sites) per month	4.4	4.8
Site inspections	277*	479

*Field man disabled for four months.

Sites closed because of completion or abandonment totaled 39, and another 38 total exemption files closed.

The Department determined six reclamation projects to have been successfully completed. These projects amount to approximately 100 acres of reclaimed ground.

As of December 31, 1978, 292 operating permits with approved plans were in effect around the State. Another 332 fee-paying certified "grandfathered" sites were ongoing. There were 591 active total exemption certificates on file. The total number of sites registered including those closed was 1,618.□

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COVER PHOTO

Oregon Portland Cement's new cement plant under construction near Durkee, Baker County (see page 58). Plant is scheduled for completion by this fall. Photo looks northward across Durkee Valley. Interstate 80-N lies to the east of the plant. (Photo courtesy Braun Studio, Ontario)

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The Special Paper series, inaugurated in 1978, comprises papers of the type earlier published as Miscellaneous Papers or Short Papers.

* * * * * * * * * * *

CONTENTS

Oregon's mineral industry in 1978

by H.C. Brooks, Resident Geologist, Baker Field Office; J.J. Gray, Economic Geologist; Len Ramp, Resident Geologist, and N.V. Peterson, District Geologist, Grants Pass Office Oregon Department of Geology and Mineral Industries

INTRODUCTION

Preliminary estimates of the value of Oregon's mineral products in 1978 total $122.7 million. This amounts to a 12 percent increase over the 1977 production of $109.1 million. The construction materials, mainly sand, gravel, stone, and cement, along with one metal, nickel, continue to be the principal products. The increased production value was due mainly to record demands for construction materials, especially cement.

At least 20 mining and exploration companies were involved in exploration for base metals, gold, silver, nickel, and uranium. An exploration highlight was the announcement of a major new uranium discovery near McDermitt in southern Malheur County.

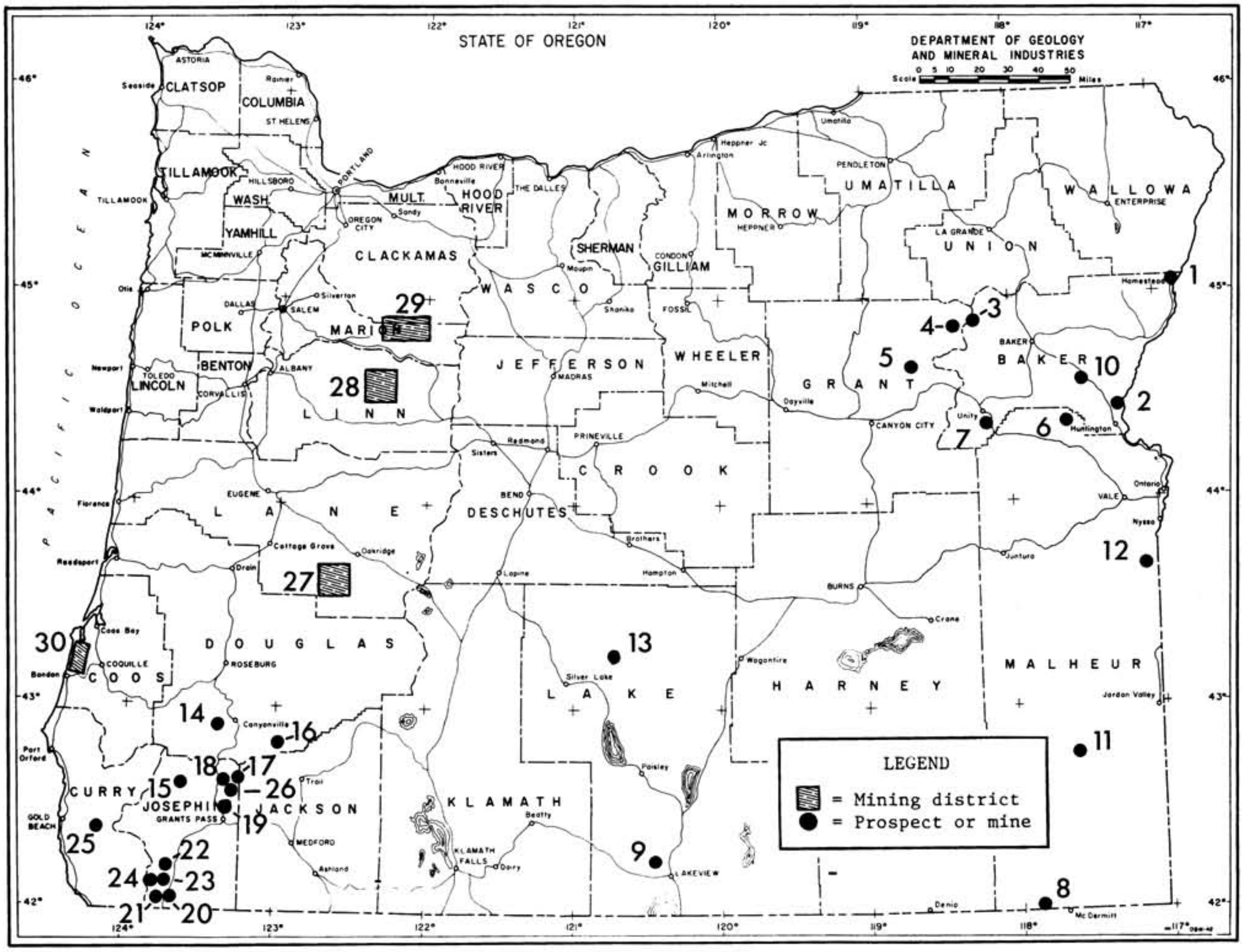
Table 1 summarizes Oregon's mineral production values for 1977 and 1978. Not included in the total is an additional $500 million worth of materials such as aluminum, ferroalloys, carbide, reactive metals, ferro-silicon, and ceramic ware from metallurgical plants and foundaries employing about 9,500.

Figure 1 shows the location of places where mining and mineral exploration occurred during 1978. Point numbers in the text refer to localities shown in Figure 1.

Table 1. Oregon's mineral production values for 1977 and 1978

	1977		1978*	
Mineral commodity	Value (thousands)	Percent	Value (thousands)	Percent
Stone	$ 39,400	36	$ 40,100	32
Sand and gravel	33,127	30	34,000	28
Cement, copper, diatomite, gold, lime, nickel, silver, talc, and tungsten	33,323	31	45,312	37
Pumice	2,429	2	2,566	2
Gemstones	520	0.5	530	0.4
Clays	193	0.2	216	0.2
Gold	100	0.1	Combined**	--
Silver	33	--	do.	--
Copper	7	--	do.	--
Total	$109,132	100	$122,724	100

* Preliminary data provided by U.S. Bureau of Mines
** Combined to avoid disclosing company confidential data



1. Iron Dyke (Cu-Au)
2. Bayhorse (Ag)
3. Meadow Lake (Cu)
4. Cougar-New York (Au-Ag)
5. Dixie Meadow (Au-Ag)
6. Basin Cr. placers (Au)
7. Unity (Cu)
8. McDermitt (U)
9. Lakeview (U)
10. Durkee (cement)
11. Rome (zeolite)
12. Adrian (bentonite)
13. Christmas Valley (diatomite)
14. Silver Peak (Cu-Zn-Ag)
15. Almeda (Ag-Cu)
16. Banfield-Rowley (Cu)
17. Gold Note (Cu-Au-Ag-Zn)
18. Copper Queen (Cu-Au-Ag-Zn)
19. Oak (Cu-Au-Ag-Zn)
20. Queen of Bronze (Cu-Au)
21. Turner Albright (Cu)
22. Eight Dollar Mountain (Ni)
23. Woodcock Mountain (Ni)
24. Rough and Ready (Ni)
25. Red Flat (Ni)
26. Greenback (Au-Ag)
27. Bohemia District
28. Quartzville District
29. North Santiam District
30. Coastal black sand deposits

Figure 1. Mineral exploration and development in Oregon in 1978. Point numbers in text refer to numbers of locations shown on this map.

INDUSTRIAL MINERALS

Sand and gravel and stone accounted for 66 percent of the value of Oregon's mineral products in 1977 and an estimated 60 percent in 1978.

The ability of sand and gravel and stone operators to maintain reserves and production capabilities that are adequate for present and future needs continues to be an important problem in some of the more populated areas of the State. Many operators face increasing pressure from State and local government agencies, environmental groups, and neighboring homeowners who are concerned about air and noise pollution connected with pit and quarry operations.

In some counties, no new pits or quarries have been allowed to open for several years. The Department continued its program of inventorying sand and

Figure 2. Oblique aerial view of city of Corvallis and two sand and gravel sites; site 1 in Linn County and site 2 in Benton County. Site 2 was isolated from the rest of Benton County when Willamette River changed channels. This photograph shows the need and opportunity for good land use planning and the relationships between urban needs, urban growth, and demand for rock material. (Photo from Short Paper 27, Rock Material Resources of Benton County, Oregon*)*

gravel resources to provide a data base for local and State land use planning. A report, *Rock Material Resources of Benton County, Oregon*, was published by the Department in 1978 as Short Paper 27 (Figure 2).

The Department also initiated a program to provide data regarding future demands for sand and gravel and stone for the State as a whole and also for selected areas. Most of the work will be done under contract by Economic Consultants Oregon, Ltd., of Eugene.

A court case involving the Oregon State Land Board and Corvallis Sand and Gravel Co. concerning ownership of a river bed after the river changed course during a flood was concluded after 20 years of litigation. The decision was in favor of Corvallis Sand and Gravel Co., now out of business. The firm's assets have been taken over by Wildish Sand and Gravel Co.

Amendments to the Federal Mine Safety and Health Act became effective in March 1978. The amendments strengthened safety rules for all surface and underground mine operations except coal mines.

Cement production expanded substantially, reflecting an increase in many types of construction in the Pacific Northwest. Oregon Portland Cement Co., with plants at Lime and Lake Oswego, is the only cement producer in Oregon. This company is continuing construction of its new cement plant near Durkee in Baker County (point 10 in Figure 1), scheduled for completion in fall 1979. Capacity of the plant will be about 500,000 tons per year, 2.5 times as great as that of the old plant at Lime, to be phased out as soon as demands for cement can be absorbed by the new plant.

Bentonite clay is being dried and bagged at a small plant near Adrian (point 12). The clay is from quarries near the head of Sucker Creek. Glen Teague is the operator.

Diatomite production in Christmas Valley (point 13) was expanded. In 1978, the capacity of the drying and bagging plant was enlarged, and a calcining kiln was installed. The calcined product is used as a filler for fertilizers and a carrier for insecticides; the uncalcined material is sold mainly for cat litter.

Figure 3. Loading soapstone blocks from deposit on Elliot Creek Ridge, southern Jackson County.

Soapstone mining in southern Oregon was the subject of an article in the September 1978 ORE BIN (Figure 3). John Pugh of southern Oregon continued to mine and market block soapstone for carving.

The extensive zeolitized tuff beds near Rome (point 11) continue to be of interest. Although there has been no commercial production, land positions are being maintained.

METALS

Oregon continued to be the only state producing primary nickel. Nickel production from the Hanna Mining Co.'s mine at Riddle (Figure 4) decreased from 14,347 tons in 1977 to 13,535 tons in 1978. Because of the high inventories of ferronickel, the smelter was closed for about 6 weeks in January and February 1978. The mine continued in operation, with the ore being stockpiled. Federal funds were available to the laid-off workers under the Trade Act of 1974 because competition from foreign imports caused the inventory buildup that forced the closure.

Oregon's production of base and precious metals has been very small for many years. In the past, however, the State has produced significant quantities of gold, silver, and copper, mostly from underground mining of narrow veins and shear zones. Some areas of the State are geologically favorable for the occurrence of large tonnage deposits of these metals, and a considerable amount of exploration work has taken place in the past few years.

EXPLORATION AND DEVELOPMENT

The 1978 exploration highlight was the announcement by Placer Development Co. of a major uranium discovery in the McDermitt area (point 8) in southern Malheur County. Thirteen million metric tons of ore containing 0.05 to 0.06 percent of U_3O_8 was indicated in December, and drilling was continuing. During the year, a claim-staking boom reminiscent of the 1950's in Utah and Colorado occurred. The area of interest extends west and southwest from McDermitt, encompassing much of the McDermitt Caldera, a huge Miocene acidic volcanic center. Many large and small mining

Figure 4. Nickel Mountain, site of only active nickel mine in United States, located near town of Riddle, Douglas County. Smelter located in background and mine employ about 580 people and annually produce ferronickel worth approximately $50 million.

companies established land positions in the area, and much exploration drilling was done during the year.

The White King and Lucky Lass Mines (point 9), northwest of Lakeview, are the only properties in Oregon that have produced any significant amount of uranium. They were operated mainly in the late 1950's. Production totaled about 200 tons of U_3O_8 from 120,000 tons of ore. Western Nuclear has owned the properties since the mid-1960's. Annual assessment work has usually included exploration drilling. The uranium mineralization is associated with Pliocene acidic volcanic and shallow-intrusive rocks. Opalization and clay alteration are prominent in the orebodies and suggest a rather low-temperature hydrothermal origin for the deposits.

A significant note is a 1977 State law forbidding radioactive waste storage in Oregon. An attorney general's opinion early in 1978 transferred regulatory authority for these materials to the Energy Facilities Siting Council. Late in the year, after two hearings, a State hearings officer recommended that waste containing more than five picocuries of radium-226 be prohibited from being stored in Oregon. This ruling could affect discovery adversely, along with the 120,000 tons of mill tailings near Lakeview from the White King and Lucky Lass Mines.

Ongoing exploration projects in eastern Oregon include the work by Birch Creek Resources, Inc., at the Iron Dyke copper mine; Ibex Minerals at the Bayhorse silver mine; Johns-Manville at their Meadow Lake copper property; W.A. Bowes and Assoc. at the Cougar and New York gold mines; and Dixie Meadow Gold Mines, Ltd., at the Dixie Meadows Mine. All of these projects have been underway for several years.

The Iron Dyke Mine (point 1) is near Homestead on the Oregon bank of the Snake River. Recorded production is about 7,000 tons of copper, 35,000 oz of gold, and 256,000 oz of silver. The main period of operation was between 1916 and 1928. The deposit is in arc-related Permian volcanic and volcaniclastic rocks. Birch Creek Resources, Inc., leased the property several years ago and has done extensive exploration work including diamond drilling.

Last September, the negotiation of a joint venture agreement with Silver King Mines, Inc., was announced. Silver King operates the Copper Cliff Mine near Cuprum, Idaho, 22 mi from the Iron Dyke. Under the agreement, Silver King will conduct underground exploration to determine the continuity of mineralization and to substantiate the copper-gold values indicated by diamond drilling. Two-thirds of the exploration will be borne by Birch Creek, one-third by Silver King. If sufficient ore is found, the two companies may form an operating partnership. Ore may be trucked 22 mi to Silver King's 800-tons-per-day flotation plant at the Copper Cliff Mine.

The Bayhorse Mine (point 2) is a few hundred feet above the level of Brownlee Reservoir on the Snake River, about 7 mi north of Huntington. The mine, last operated in the late 1920's, has produced about 286,000 oz of silver. In 1975, Ibex Minerals, Inc., began an exploration program which included rehabilitation of the old workings, diamond drilling, and a limited amount of underground exploration. In August 1978, Ibex was joined by Centennial Exploration Co. in an agreement to continue the exploration program and to form an operating partnership if an adequate tonnage of ore is found.

At their Meadow Lake copper prospect (point 3) on Elkhorn Ridge (Figure 5) west of Baker, Johns-Manville did a small amount of diamond drilling as part of the 1978 assessment work. Johns-Manville began exploration in this area in 1971. More than 200 claims are involved. The host rock is granodiorite of the Jurassic Bald Mountain batholith. The prospect area is in the heart of the Twin Mountain RARE II area.

The Cougar and New York Mines (point 4) are in the Granite gold mining district in Grant County. Both mines produced small amounts of gold prior to 1942. They were developed in gold-quartz veins in argillite and chert of the Permian Elkhorn Ridge Argillite near the southwest margin of the Jurassic Bald Mountain batholith. W.A. Bowes and Assoc. began work to reopen the mines in 1974. Equipment for heap-leach cyanidation, including a 280-by-90-ft asphalt pad and tailing storage pond, has been installed. Work at the Cougar Mine in 1978 involved running a decline to intercept the Cougar vein beneath the old workings.

Exploration and development work at the old Dixie Meadows Mine (point 5) in the Quartzburg District, north of Prairie City, has been underway for about 5 years. Late in 1978, the property was sold to Canadian Natural Resources, Ltd., of Vancouver, B.C. Mineralization is associated with a shear zone that averages about 60 ft in width and dips 65 degrees. The country rock is a complex of greenstone, diorite, serpentinite, and argillite. The mineralized material is fault-brecciated country rock that locally has been partly replaced by quartz, sericite, and sulfide minerals, including pyrite, arsenopyrite, chalcopyrite, pyrrhotite, galena, marcasite, and sphalerite.

In the Basin Creek area (point 6), placer mining for gold continued. Operations have been sporadic. Small washing plants are utilized to treat terrace gravels about 150 ft above the present level of Basin Creek. The creek bed was worked extensively in the late 1800's. Water is scarce for mining the terrace deposits.

Point 7 indicates the location of a large group of mining claims filed by Johns-Manville Co. in the Camp Creek drainage southeast of Unity. More than 300 claims have been located. Johns-Manville's interest in the area followed a stream-sediment geochemical sampling program sponsored by the Oregon Department of Geology and Mineral Industries which disclosed zinc and copper anomalies in the area. According to existing geologic maps, the area includes Jurassic marine sedimentary rocks and small granitic intrusives. A regional geologic mapping program has been initiated by the Department.

In southwestern Oregon, firms involved in exploring for volcanogenic sulfide deposits containing copper, gold, silver, and zinc include American Selco, Asarco, Canadian Superior, Chevron, Cominco, Conoco, Gulf Minerals, Newmont, and Noranda.

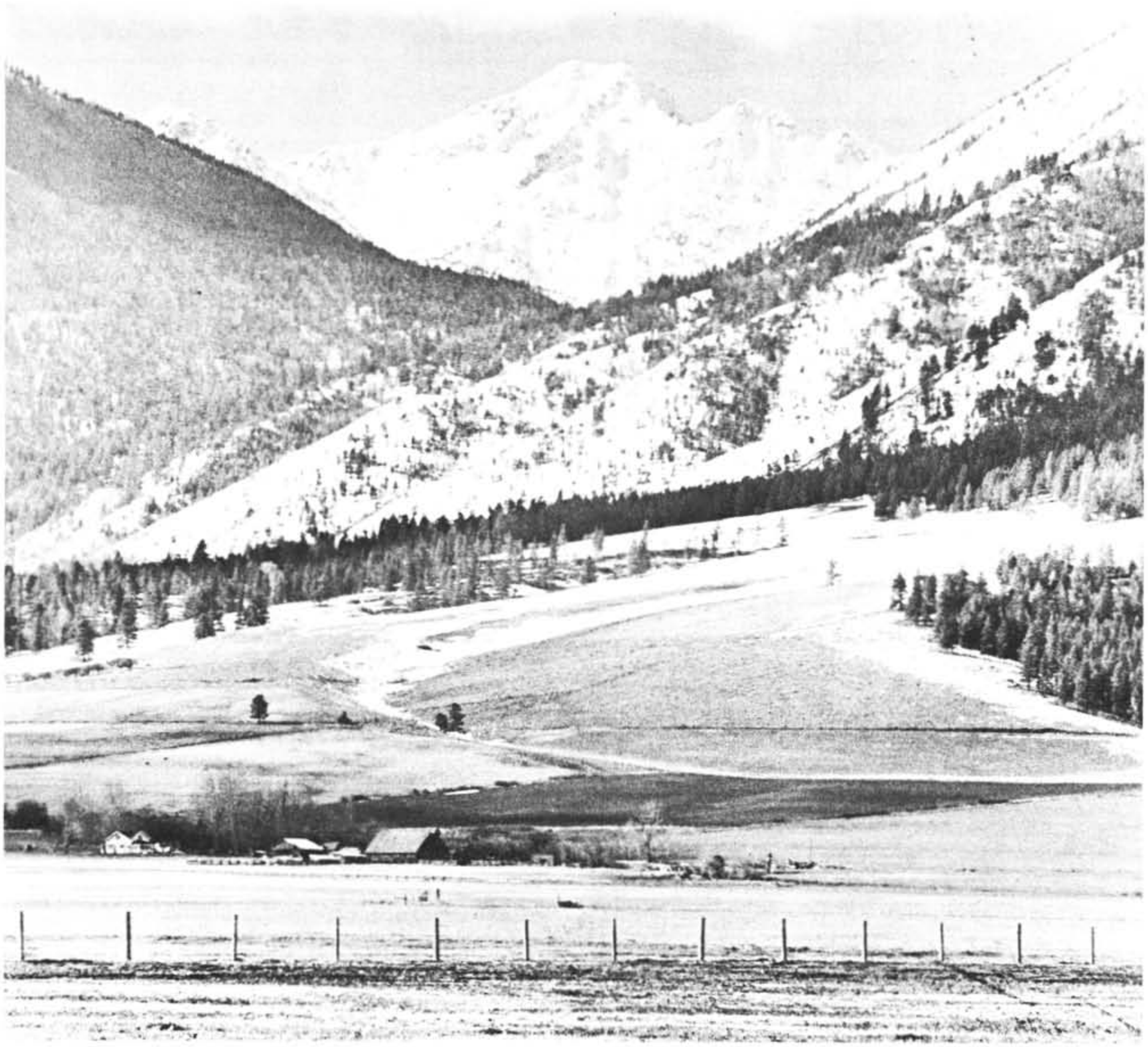


Figure 5. View of Elkhorn Ridge, looking west from a point 15 mi northwest of Baker, Baker County. Johns-Manville has been conducting exploration in this area since 1971. (Photo courtesy Baker Democrat Herald*)*

The principal area of interest has been the Big Yank mineralized zone that extends from the Silver Peak Mine (point 14) in southern Douglas County to the Almeda Mine (point 15) in northern Josephine County, a distance of about 20 mi. The deposits consist of disseminated and massive sulfides, mainly pyrite, chalcopyrite, and sphalerite in Jurassic metavolcanic rocks. Total production of the several mines and prospects in this zone has been about $350,000 in copper, gold, and silver, all prior to 1930. The country rocks have been silicified and in places replaced by massive barite. Chevron continues active exploration at the Silver Peak Mine and surrounding area, and Newmont is conducting preliminary geophysical surveys south of the Almeda Mine near Galice.

Other volcanogenic sulfide deposits that received attention include the Banfield and Rowley Mines in southeastern Douglas County and scattered deposits in Josephine County, including the Oak, Copper Queen, Gold Note, Turner-Albright, and Queen of Bronze Mines. The Rowley and Banfield Mines (point 16) are about 7 mi south of Tiller. The deposits are in a body of schist and gneissic amphibolite. Jurassic quartz diorite and small Tertiary andesite intrusives are exposed nearby. The ore minerals are disseminated chalcopyrite, sphalerite, and pyrite accompanied by hydrothermal alteration of the host rocks. The mineralized zones range from 10 to 150 ft wide and are several hundred feet long.

At the Queen of Bronze Mine (point 20), lenticular bodies of massive sulfides as large as 10,000 tons have been mined. Ore minerals include pyrite and chalcopyrite, with smaller amounts of pyrrhotite and sphalerite. Ore shipped prior to 1930 averaged 8.3 percent copper, 0.13 oz gold, and 0.16 oz silver per ton. Total production of the mine is estimated at about $1.35 million from 35,000 tons of ore. The deposits are in greenstone of the Triassic Applegate Group. During 1977, Canadian Superior rehabilitated and sampled the underground workings. This work is being evaluated.

Nickel exploration in southwestern Oregon and northern California picked up markedly, mainly due to the activity of Canadian stock companies. Detailed sampling of the laterite with a reverse circulation drill continued most of the summer on Eight Dollar Mountain (point 22) by U.S. Nickel Corp. of Vancouver, B.C.

Inspiration Development Co. continued its nickel exploration activity, mainly in the Rough and Ready Creek area (point 24) of southern Josephine County, conducting seismic exploration, back-hoe sampling, and some ore-dressing tests. Coastal Mining Co. (Hanna Mining) has kept its nickel laterite claims in northern California and southern Oregon, including Woodcock Mountain (point 23) in Josephine County and Red Flat (point 25) in Curry County.

Investigations of Nickel in Oregon (Miscellaneous Paper 20), a detailed report on nickel investigations in Oregon, was published by the Oregon Department of Geology and Mineral Industries. The U.S. Bureau of Mines conducted field investigations of nickel, chromium, and cobalt-bearing laterite resources in Josephine County in support of related metallurgical work being conducted at their research center in Albany. During the summer of 1978, the Bureau of Mines also conducted a drilling project along the Oregon coast to evaluate the chromite content of the black sand deposits (point 30).

There are still a number of small-scale itinerant gold placer operations producing small quantities of gold nuggets for sale both to individual investors and for jewelry. Operations are mainly in Josephine and Jackson Counties, along the Rogue, Applegate, and Illinois Rivers and their tributaries. Some activity has also been reported in the upper Chetco and south fork of the Sixes River in Curry County. No one operation has been steady, but production from all may be in the range of 200 oz annually.

Small-scale mining and milling has been carried on by Wesley Pieren, owner, at the old Greenback Mine (point 26), historically the largest producer of gold in southwestern Oregon.

The U.S. Geological Survey and U.S. Bureau of Mines both had crews of geologists mapping and evaluating mineral resources in the expanded Kalmiopsis Wilderness Area. The U.S. Geological Survey is continuing geologic mapping and mineral resource evaluation of the Medford 1° by 2° Quadrangle. The Oregon Department of Geology and Mineral Industries is preparing a geologic map and mineral resource inventory of Josephine County to be published in 1979.

In northwestern Oregon, exploration for copper-lead-zinc and copper-molybdenum deposits continues in the Bohemia, Quartzville, and North Santiam Mining Districts. In the North Santiam District (point 29), Amoco did some geological, geochemical, and geophysical work and some test drilling on a block of 200 claims. Cominco American did geological and geophysical work on a block of claims in the Quartzville District (point 28). Some properties changed hands in the Bohemia District (point 27). ⚒

Next month

Plate tectonics and the geologic history of the Blue Mountains
by Howard C. Brooks, Oregon Department of Geology and Mineral Industries

Petroleum source rock tests on two central Oregon wells

by Vernon C. Newton, Jr., Petroleum Engineer, Oregon Department of Geology and Mineral Industries

When the Department loans well samples to exploration companies for special studies, it requires that test results be submitted to the Department if testing causes a loss of some of the sample. The following results of source rock tests for two central Oregon wells were obtained in this fashion. The name of the company supplying test results is withheld for proprietary reasons. The laboratory tests reported here were made on core samples from the Standard-Sunray Mid-Continent Bear Creek #1, SE¼ sec. 30, T. 17 S., R. 15 E., Crook County; and Standard Kirkpatrick #1, SW¼ sec. 6, T. 4 S., R. 21 E., Gilliam County (see table).

The maturation of organic debris deposited in sediments can be measured by a number of characteristics. Alteration of organic material is dependent on three main factors: depth of burial, paleotemperature, and the time duration of the burial. Source rock studies can qualify petroleum potential of sedimentary rock units by identifying certain organic indices. Two main types of organic material buried with sediments are those originating from marine micro-organisms with some mixing of land plants and those derived from continental higher order plants. Figure 1 shows that oil is most likely to be generated in organically rich sedimentary deposits if paleotemperature is in the 60°to 130°C. range, petroleum gas (wet gas) in the range of 130° to 165°C., and dry gas (methane) from 165° to 200°C. The average corresponding burial depths for the three temperature ranges is 1.8 to 4.0 km, 4 to 4.8 km, and 4.8 to 6.5 km for dry-gas generation.

Judging by the vitrinite reflectance factor (R_o) on Figure 1, all except one of the samples tested have good potential for producing oil. Core 6304-6309 from the Bear Creek well suggests that rock

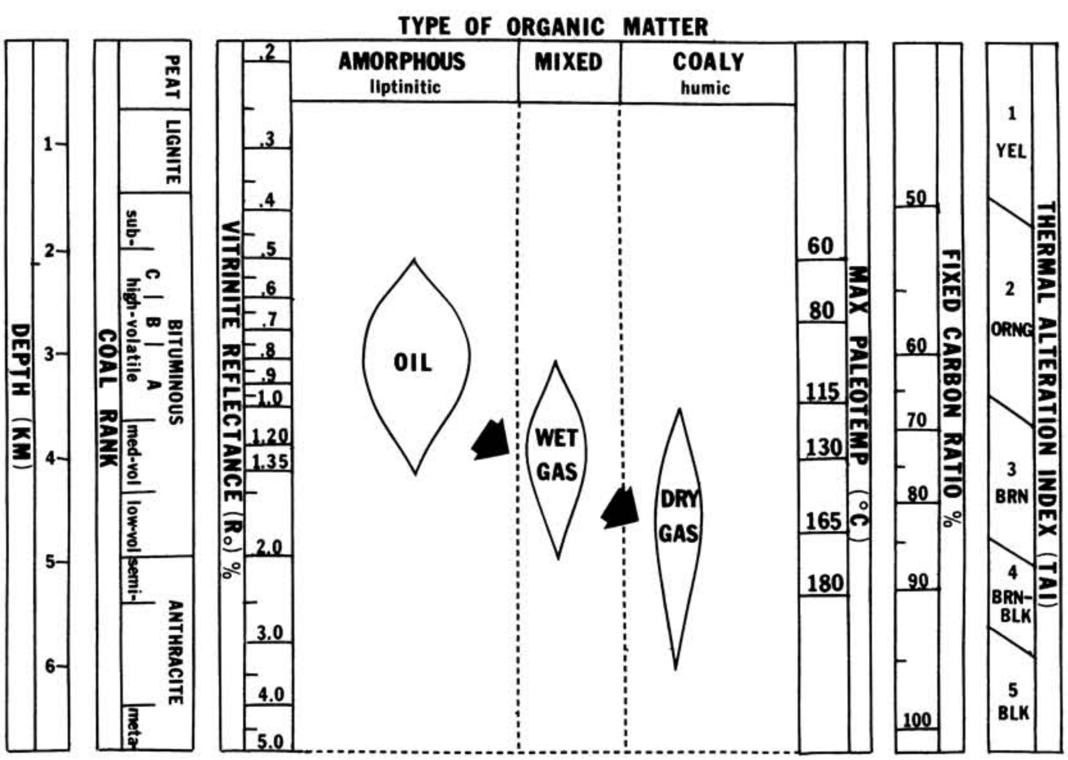


Figure 1. Correlation of organic maturation indices. (After Dow, 1978; Kantsler and Smith, 1978; and Vassoyevich, 1970)

Petroleum source rock data												
Well	Sample interval (ft)	Organic carbon content (wt %)	H/C[1]	Kerogen description				TAI[5]	R_o[6] (range)	R_o (mean)	N[7]
				% Alginite[2]	% Exinite[3]	% Vitrinite[4]	% Other				
Bear Creek #1	3,489-3,496	0.81-0.76	0.51	0	0	20	80	ND[8]	0.62-0.78	0.72	5
Bear Creek #1	4,413-4,475	0.90	0.62	0	0	20	80	ND[8]	0.67-0.84	0.75	40
Bear Creek #1	5,311-5,320	0.68	0.54	0	0	5	95	ND[8]	0.95-1.20	1.12	30
Bear Creek #1	5,826-5,841	0.85	0.53	0	0	10	90	ND[8]	1.16-1.42	1.30	40
Bear Creek #1	6,304-6,309	1.18	0.55	0	0	30	70	ND[8]	1.30-1.54	1.43	40
Kirkpatrick #1	8,385-8,393	0.80	ND[8]	0	0	20	80	2.7	0.90-1.13	1.04	40

[1]Atomic hydrogen to carbon ratio.
[2]Algal debris + amorphous sapropels.
[3]Plant cuticle + spore and pollen exines + resins.
[4]Woody tissue altered in a wet anoxic environment.
[5]Thermal Alteration Index.
[6]Vitrinite reflectance.
[7]Number of points used to obtain R_o mean.
[8]No data (recovery too low, no spores or pollen, bad sample quality, etc.).

strata at this level and below would probably produce wet gas. This means that rocks below a depth of 1.83 km in the Bear Creek area either were buried 2 km deeper in the past or were subjected to a much higher paleotemperature at a shallower depth over a long time span. Results of tests on the remaining samples indicate burial depth was greater by 1.4 to 2.0 km in the past or the rocks were subjected to higher than normal paleotemperatures. If paleotemperatures were near normal in the area, the region has been uplifted approximately 2 km since deposition of the oldest rocks.

In general, paleoenvironments and geologic history can best be reconstructed from stratigraphic, paleontologic, and structural information. Source rock indices are then used as supplementary data.

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Kantsler, A.J., and Smith, G.C., 1978, Rank variations, calculated paleotemperatures in understanding oil and gas occurrence: Oil and Gas Journal, Nov. 20, 1978, p. 196-205.

Vassoyevich, N.B., and others, 1970, Principle phase of oil formation: International Geology Review, 12, p. 1276-1296. ⚒

Department announces new geothermal publication

Newest publication of the Oregon Department of Geology and Mineral Industries is "Low- to Intermediate-Temperature Thermal Springs and Wells in Oregon" (GMS-10). This map, part of the Department's Geological Map Series, is an update of Miscellaneous Paper 14, published in 1970.

Compiled by R.G. Bowen, N.V. Peterson, and J.F. Riccio, the map is on a scale of 1:1,000,000 (1 in. = 16 mi). A table with such information as locations, water temperatures, and references is printed on the back of the map.

Recreationists and tourists, as well as geologists, engineers, geothermal developers, and government agencies, will find the information interesting and useful.

GMS-10 is available at the Department's Portland, Baker, and Grants Pass offices (see inside front cover for addresses). GMS-10 costs $2.50 per copy. Payment must accompany orders of less than $20.00. ⚒

Current Department activities

The Department of Geology and Mineral Industries has several current projects involving mineral resource appraisal and hazards studies as part of its ongoing survey of Oregon's geology and mineral resources. These projects will be described individually in detail in subsequent issues of OREGON GEOLOGY.

JOSEPHINE COUNTY MINERALS INVENTORY

Len Ramp and Norman V. Peterson of the Department's Grants Pass field office are working on an updated inventory of metallic and nonmetallic minerals in Josephine County in southwestern Oregon. A new geologic map of the County is being prepared. This project is jointly sponsored by the Department and Josephine County.

BLUE MOUNTAINS MAPPING

In the Blue Mountains in eastern Oregon, Howard C. Brooks of the Baker field office has begun detailed mapping of an area in southwestern Baker County which contains numerous old mines and promising prospects and which is undergoing increasing study by industry.

ECONOMIC DEMAND MODEL

Jerry J. Gray of the Albany office is working jointly with Economic Consultants Oregon, Ltd., to prepare a long-term economic demand model of sand, gravel, and crushed stone consumption in the State and several important sub-State marketing areas. This study represents a first attempt to appraise adequately Oregon's future needs for these basic construction materials on a statewide basis. The demand model is part of a larger project involving the Department of Land Conservation and Development and the Division of State Lands. Funding is being provided by the Pacific Northwest Regional Commission and the U.S. Army Corps of Engineers.

MT. HOOD GEOTHERMAL ASSESSMENT

The Department, in cooperation with the U.S. Department of Energy, U.S. Geological Survey, and U.S. Forest Service, has just completed the second field season of a detailed study of Mt. Hood Volcano, with the goal of identifying geothermal resources. The Department's work, headed by Joseph F. Riccio, includes drilling, geochemical, geophysical, and geologic studies.

STATEWIDE LOW-TEMPERATURE GEOTHERMAL INVENTORY

The low-temperature geothermal energy potential of eight areas in the State is being investigated. The study is receiving funding from the U.S. Department of Energy. Many of these areas are in eastern Oregon. They will be evaluated in more detail during the next two to three years.

COOS BASIN OIL AND GAS

A joint project, funded by the Department of Land Conservation and Development, Coos County, and private firms, under the management of Vernon C. Newton, petroleum engineer in the Portland office, is aimed at assessing petroleum and natural gas potential in the coastal portions of Coos and Douglas Counties. One purpose is to provide data to guide policy formulators at the State and local levels.

WASTE DISPOSAL

James Bela of the Portland office is compiling geologic information pertaining to northeastern Oregon. The study is part of a Federally sponsored investigation of the Columbia Plateau in Washington State as a site for deep storage of radioactive waste or spent fuel.

CLACKAMAS COUNTY GEOLOGIC HAZARDS

Herbert G. Schlicker of the Portland office is engaged in an appraisal of landslides and other geologic hazards in Clackamas County, with funding provided jointly by the Department and the Department of Land Conservation and Development.

EASTERN BENTON COUNTY GEOLOGIC HAZARDS

James Bela has recently completed a study of the geology of eastern Benton County which will be published in the near future. ⚒

OMSI summer program announced

This summer, the Oregon Museum of Science and Industry and the National Science Foundation will present another 8-week high school paleobotany program.

From June 17 to August 11, a team of 10 students, based at Hancock Field Station near Fossil, will participate in a controlled excavation of fossil leaves, wood, and fruits from the Eocene Clarno Formation. Laboratory work will include preparation and analysis of fossils recovered.

Tuition for the entire program, including room, board, instruction, and laboratory facilities, will be approximately $450. Bruce Hansen, at OMSI Research Center, 4015 S.W. Canyon Rd., Portland, Oregon 97221, can supply application forms and additional information. ⚒

Water Law Short Course set

The Natural Resources Law Institute and the U.S. Fish and Wildlife Service's Cooperative Instream Flow Service Group will cosponsor a Water Law Short Course in Boise, Idaho, May 1-3, 1979.

The course covers basic principles of surface waters regulation and management, with special emphasis on the protection of instream uses of water. It is designed for employees of government agencies and private industry, but anyone interested in water law may attend.

The Natural Resources Law Institute, 10015 S.W. Terwilliger Blvd., Portland, Oregon 97219; (503) 244-1181, extension 643, can provide further information. ⚒

ASM to give scholarships

The Oregon chapter of the American Society for Metals has established a new $500 scholarship to the Oregon State University engineering school.

Each spring the mechanical engineering faculty will select the winner, who will be a junior working for a degree in mechanical engineering with a minor in material sciences. The first award will be made in May. ⚒

meeting announcements

Each month, space permitting, upcoming meetings will be announced in this column. Information should reach our office no later than six weeks before a meeting. Please be specific and give full name of the organization; exact subject, location, and time of the meeting; and the name, address, and phone number of person to contact for questions or reservations.

April AIME meeting planned

The Oregon Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers will meet on Friday, April 20.

Chairman William D. McMillan announces that a speaker from Portland General Electric Co. will discuss the Boardman coal-fired plant.

Meeting place will be the High Hat Restaurant, 11530 S.W. Barbur Blvd., Tigard, near the Tigard exit off Interstate 5.

The schedule includes a social hour at 6 p.m., dinner at 7, and speech at 8.

For reservations, call or write to the Oregon Department of Geology and Mineral Industries, Portland Office (see inside front cover), by April 18.

GSOC re-views eclipse

Topic of the April 20 luncheon meeting of the Geological Society of the Oregon Country will be the recent solar eclipse. Gary Stasiuk, Planetarium Director for the Oregon Museum of Science and Industry, will make a slide presentation.

GSOC luncheon meetings are held at noon in Room A, adjacent to the cafeteria on the third floor of Standard Plaza, 1100 S.W. Sixth, Portland.

Viola L. Oberson, luncheon program chairperson, can give more details to anyone interested. Her telephone number is 282-3685. ⚒

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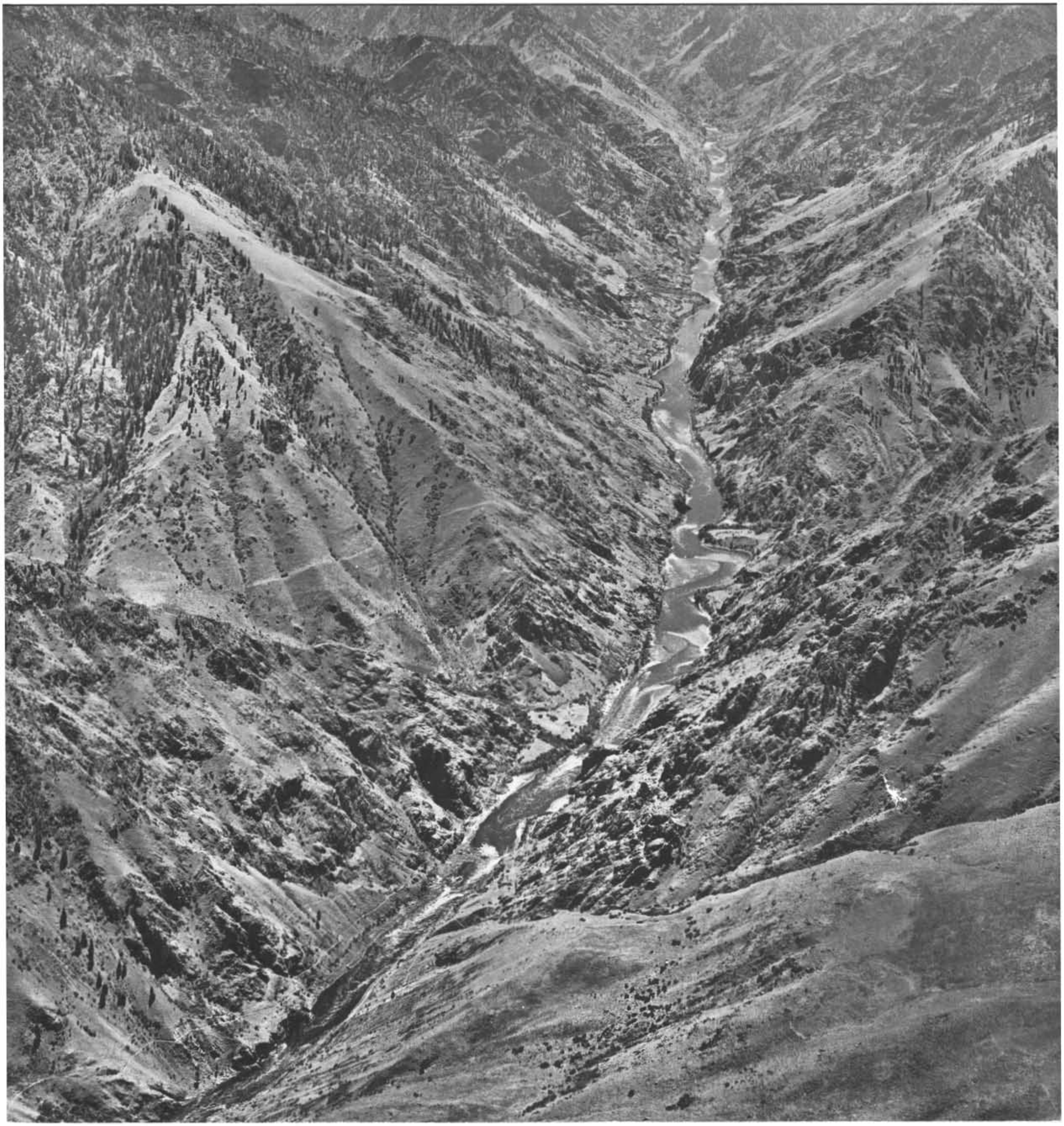

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COVER PHOTO

Aerial view of Hells Canyon of Snake River, looking upriver to south near Hat Point. Saddle Creek is in right middle ground. Rocks are primarily pre-Tertiary volcanic and volcaniclastic rocks of Wallowa-Seven Devils volcanic arc terrane (see article beginning p. 71). (U.S. Forest Service photo)

NOTICE TO CONTRIBUTORS

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

1. All material should be typewritten, double-spaced, with one-in. margins.
2. In general, articles, including tables, artwork, and photos should not exceed 20 pages in length. Longer articles might be published in two installments.
3. Drafted material must be submitted in final form. If reduction will be necessary, lettering should be large enough to be legible after reduction.
4. Photos should be black-and-white glossy prints. If slides or color prints are the only photos available, consult with the editor.
5. All artwork and photos must be clearly marked. Figure references should be placed in appropriate places in the text. A separate typed list of figure captions should accompany the article. All artwork and photos become the property of the Department, unless other arrangements are made prior to publication.
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7. Except for units of measurement, do not abbreviate.
8. Authors (or first author in the case of multiple authorship) will receive 25 complimentary copies of the issue of OREGON GEOLOGY in which their article appears.

* * *

TO OUR READERS

Readers will note that this month's issue of Oregon Geology has been typeset. We are trying typesetting because we believe it will increase our efficiency, improve readability, and enable us to get much more information onto each page. We invite your comments on this new step.

* * *

CONTENTS

Plate Tectonics and the Geologic History of the Blue Mountains

by H.C. Brooks, Resident Geologist, Baker Field Office, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Rocks which make up the Blue Mountains of northeastern Oregon and adjacent western Idaho are divided into two main groups on the basis of their geologic ages and origins. The older of the two groups ranges from Devonian to Late Jurassic in age and is made up chiefly of rocks which at one time were part of an ancestral Pacific Ocean. According to plate tectonic theory, these rocks represent fragments of ancient ocean floor and volcanic islands that were broken up, moved across some unknown breadth of ocean, and added onto what was then the outer edge of the continent. This accretionary expansion of the continent took place between Late Triassic and Late Jurassic time.

The younger group of rocks is of Cenozoic age and consists of sedimentary and volcanic rocks that were deposited on dry land or in freshwater lakes on top of the older rocks after they had become part of the continent. Erosion has removed the Cenozoic rocks in many places, exposing pre-Cenozoic rocks.

In this report only the pre-Cenozoic rocks are discussed. Preceding the discussion is an outline of some basic concepts of plate tectonics for those readers who are not familiar with the subject. The interested reader is encouraged to consult recent geologic textbooks for more thorough discussions of the theory.

This discussion of plate tectonics and the Blue Mountains is largely a synthesis of information presented in recent publications by Brooks and others (1976), Vallier and others (1977), Thayer (1977), Vallier (1977), Brooks and Vallier (1978), Dickinson and Thayer (1978), Hamilton (1976; 1978a, b), and Dickinson (1979).

PLATE TECTONIC THEORY

The basic tenet of the theory of plate tectonics is that the outer rind of the earth is divided into giant plates that are in motion relative to one another (Figure 1). The plates are rigid and float on a relatively plastic and deformable substratum. They are about 80 km thick and comprise the outermost layer of the earth (the crust) and the upper part of the underlying layer (the mantle).

This rigid outer portion of the earth is called the lithosphere. The plastic layer on which the lithospheric plates move is lower in the mantle and is called the asthenosphere.

All of the lithospheric plates are moving more or less continuously—pulling apart, pushing together, slipping past or sliding under one another like ice floes in a river. They are constantly changing in size and shape. Zones with frequent earthquakes outline the boundaries of the plates. Motion of the plates results in relative displacements between adjacent plates ranging from less than 1 to about 13 cm per year. The velocities are unimpressive until one realizes that 5 cm per year amounts to 50 km per million years, and some plate movements have been under way for at least 100 million years.

Where plates are moving away from one another, hot plastic material (magma) from the mantle flows upward to fill the fissures which open between them and solidifies to become part of the trailing edges of the separating plates (Figure 2). New crust is thereby created. Because most of the rift zones where plate material is being created are in the middle of the ocean floor, this process is called sea-floor spreading. Presently, the plates are separating and gaining new material primarily along a system of submarine ridges more than 64,000 km in total length that branches through all the world's oceans like the seam of a baseball. A ridge forms between the separating plates because the new material is hot, lower in density, and rides relatively high on the asthenosphere. As the plates move apart, the material cools, becomes higher in density, and rides lower on the asthenosphere.

Where the plates converge, one is deflected downward so that it slides beneath the leading edge of the other and then is carried back into the earth, where it is recycled. Old crust is thereby destroyed. Overall plate consumption must progress at the same rate as plate growth. Generally, oceanic plates slide beneath continental plates or other oceanic plates.

As the oceanic plates move about, they accumulate an overlayer of sediments consisting partly of material eroded from continents and islands and partly of the remains of oceanic micro-organisms. When the cooled oceanic plate with its overlying layer of sediment is carried down into the hotter mantle at subduction zones, selective melting of the lighter materials, including the sediment, occurs.

Part of the melted material rises and reaches the surface of the overriding plate, producing a zone of volcanic activity called a volcanic arc; part of it crystallizes before reaching the surface, either in the roots of the volcanoes or in the crust beneath them (Figure 2).

Large intrusive bodies of rock that crystallize underground from a melt are called plutons; large plutons (over 100 sq km in area) are called batholiths, and smaller ones are called stocks. Sheetlike intrusive igneous rocks that cut across the planar structure of surrounding rocks are called dikes; those that parallel the structure are called sills.

As the oceanic crust descends beneath the volcanic arc, it provides a replenishable source of magma so that the volcanic (extrusive) and plutonic (intrusive) buildup of the arc may continue for many millions of years. Volcanic arcs may form on the floors of ocean basins or along continental margins, depending on the locations of the subduction zones. Offshore volcanic arcs often appear as strings of volcanic islands known as island arcs. The Pacific Ocean is ringed with island arcs. The Aleutian Islands and the Japanese Islands are prime examples. The Andes Mountains of South America and the Cascade Mountains of Oregon and Washington are examples of volcanic arcs that are built on continental margins.

Subduction zones are marked by trenches, great linear depressions in the ocean floor. Trenches are repositories for accumulations of sediment derived mainly from overriding plates. Sediment deposited on a trench floor is carried beneath the margin of the overriding plate by the descending plate unless the rate of sediment accumulation exceeds the rate of subduction, in which case part of the sediment piles up against the wall of the trench.

The parts of a growing volcanic arc which rise above sea level are subjected to erosion; as a result, volcanic and sedimentary rocks are mixed and interlayered. Some sediment is carried toward the ocean and deposited in the area between arc and trench. This area is known as the arc-trench gap or forearc basin. Also, some sediment is carried toward the continent and deposited between the arc and the continent.

The continents and ocean basins are distinctly different parts of the plates and are affected differently during plate movements. Nearly all plates consist of both continental and oceanic portions that move together as a unit. Because it is made of lighter material, continental crust is much thicker than oceanic crust, and for the same reason, continents stand higher than ocean basins. Oceanic crust is generally about 5 km thick. Average thickness of continental crust is about 35 km; thickness under mountain ranges may be as much as 60 km.

Sooner or later, all ocean floors will be replaced as new crust is created at spreading ridges and old crust is consumed in subduction zones. The most ancient segment of the present ocean floor anywhere in the world is less than 200 million years old, whereas some parts of the continents are more than 4 billion years old. Presumably, continental crust is too buoyant to be resorbed into the mantle at subduction zones.

Continents may split and the pieces may drift apart as new oceanic crust is formed between them. Continents on opposite sides of a spreading ridge move farther apart as new oceanic crust is created at the spreading ridge. Continents on opposite sides of a subduction zone move closer together as old oceanic crust is consumed in the subduction zone. Where oceanic crust disappears between them, continents are slowly jammed together with such deforming force that mountains are formed. The Himalayan and Alpine Mountains are examples of mountains formed by colliding continents. In the same manner, island arcs collide with continents and become part of mountain belts along the margins of continents. Continents may grow by the magmatic construction of volcanic arcs along their margins and by the accretion of volcanic arcs which were constructed on the ocean floor. There are no ancient arcs in the present oceans, just as there are no really ancient ocean floors. All old island arcs have presumably become parts of the continents.

Associated with arc volcanic and related rocks in many mountain belts are suites of rocks called ophiolites, generally regarded as remnants of oceanic crust and upper mantle which were not totally consumed at subduction zones. Major components of intact ophiolite successions are, from bottom to top, peridotite, gabbro, basalt, and oceanic sediments. Many ophiolite successions also include quartz diorite and albite granite (plagiogranite) in the upper part of the intrusive complex and keratophyre and quartz keratophyre lava and tuff in the extrusive sequence. Most ophiolite sequences are capped by fine-grained sedimentary rocks, usually including chert and argillite which were deposited in layers on top of the oceanic crust as it moved away from the spreading ridge.

The mountainous region of the western United States west of the Rocky Mountains is known as the Cordilleran Orogen. The Cordillera is divided into two belts which roughly parallel the present Pacific continental margin. The eastern belt consists mainly of marine sedimentary rocks derived from erosion of continental rocks and deposited on the continental margin. The western belt is made up mainly of fragments of oceanic crust and volcanic arcs and their associated sedimentary terranes that were swept against the continent on moving oceanic lithosphere. The approximate location of the continental margin at different times during the Mesozoic is shown in Figure 3.

Pre-Cenozoic rocks in the Blue Mountains are among the easternmost exposures of the western belt of accreted terranes. Oceanic crust (ophiolite) and volcanic island arc terranes of the Blue Mountains region were accreted to the continent during the Late Triassic to Early Cretaceous interval of geologic time. The contact between these rocks and rocks of the eastern, nonvolcanic portion of the Cordillera is obscured by the Idaho Batholith, of Late Cretaceous and younger age.

PLATE TECTONIC TERRANES IN THE BLUE MOUNTAINS

Pre-Cretaceous rocks in the Blue Mountains are divided into four terranes: oceanic crust terrane, Wallowa-Seven Devils volcanic arc terrane, Huntington volcanic arc terrane, and forearc basin terrane. The rocks in all terranes are metamorphosed to varying degrees and intruded locally by late Mesozoic granitic plutons. Devonian through Jurassic rocks are present, but rocks ranging from Permian through Jurassic age are most abundant.

Oceanic crust terrane

The oceanic crust terrane represents oceanic crust and its overlying (supracrustal) cover, consisting of sedimen-

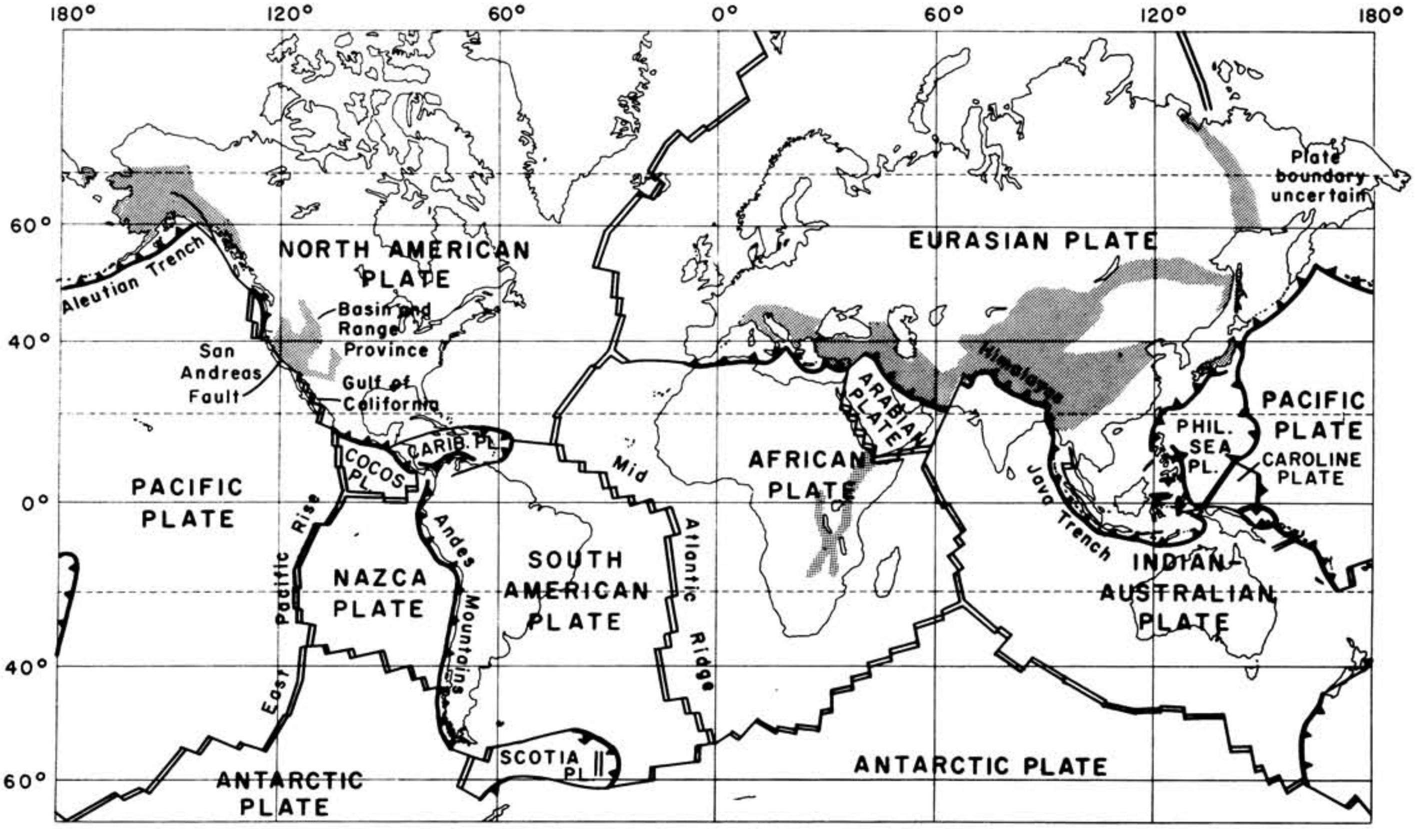


Figure 1. Lithosphere plates of the world, showing presently active boundaries. Double line: zone of spreading, where plates are moving apart. Line with barbs: zone of underthrusting (subduction), where one plate is sliding beneath another; barbs on overriding plate. Single line: strike-slip fault, along which plates are sliding past one another. Stippled area: part of a continent, exclusive of that along a plate boundary, which is undergoing active extensional, compressional, or strike-slip faulting. Compiled and adapted from many sources; much simplified in complex areas. (From Hamilton, 1978. Map courtesy California Division of Mines and Geology)

tary and volcanic rocks. Both crust and cover were severely broken up, rearranged, and deformed before and during late Mesozoic time, when the terrane became attached to the western edge of North America. Fragments of ophiolite successions are scattered throughout the terrane.

Included in the ophiolite fragments are ultramafic rocks, gabbro, quartz diorite, and albite granite in various proportions in different places. The supracrustal sedimentary and volcanic rocks are mainly chert, argillite, tuff, and lava flows, with scattered pods and lenses of limestone. Tectonic blocks of limestone and chert have yielded fossils ranging from Devonian to Middle Triassic age. Therefore, the oceanic crust terrane probably does not represent a single piece of ocean floor that has been broken up. More likely it represents a collage of pieces of several different generations of crust, broken and deformed both before and while they were being assembled by plate tectonic forces, probably near a subduction zone. Most of the rocks are severely deformed by folding and faulting. Major rock types typically are separated by faults or shear zones rather than depositional or intrusive contacts. The term "mélange" is often used to describe the chaotic mixture of rock types.

The largest intact exposure of the ophiolitic rocks is centered in Canyon Mountain, southeast of John Day (Figure 4), and is known as the Canyon Mountain Complex (Thayer, 1963). The rocks of this complex and their stratigraphic and structural relationships have been discussed in considerable detail (Thayer, 1963, 1977; Thayer and Brown, 1964; Avé Lallemant, 1976). The complex is 17 to 20 km long by 8 to 13 km wide and is about 150 km^2 in area. A block of serpentinized peridotite and gabbro that has been intensely deformed at high temperature forms 80 percent of the complex, and a sheeted dike complex makes up the remaining 20 percent. The complex is divided into three east-west belts with ultramafic rocks on the north, gabbro in the middle, and the sheeted dike complex of quartz diorite, albite granite, and keratophyre on the south. The sheeted dike complex was intruded into the peridotite and gabbro of the Canyon Mountain Complex and is believed to constitute the substructure of volcanoes that formed on the ocean floor in Permian and early Mesozoic time. Ages obtained from radioactive isotope dating of the Canyon Mountain Complex and associated metamorphic rocks nearby range from 250 to 186 million years.

Other large exposures of ophiolitic rocks occur in the Virtue Hills and Sparta areas east of Baker. East of Elkhorn Ridge, the rocks are mostly gabbro, quartz diorite, and albite granite. Ultramafic rocks make up a very small percentage of the total outcrop area.

The mix of rock types in the supracrustal assemblage

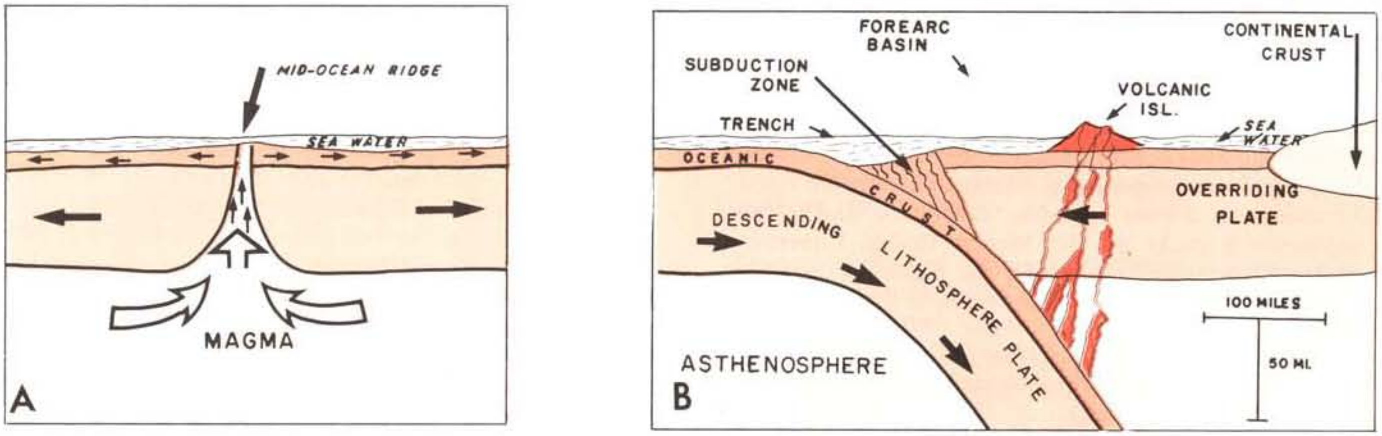


Figure 2. Schematic models of separating and converging plates of oceanic lithosphere.

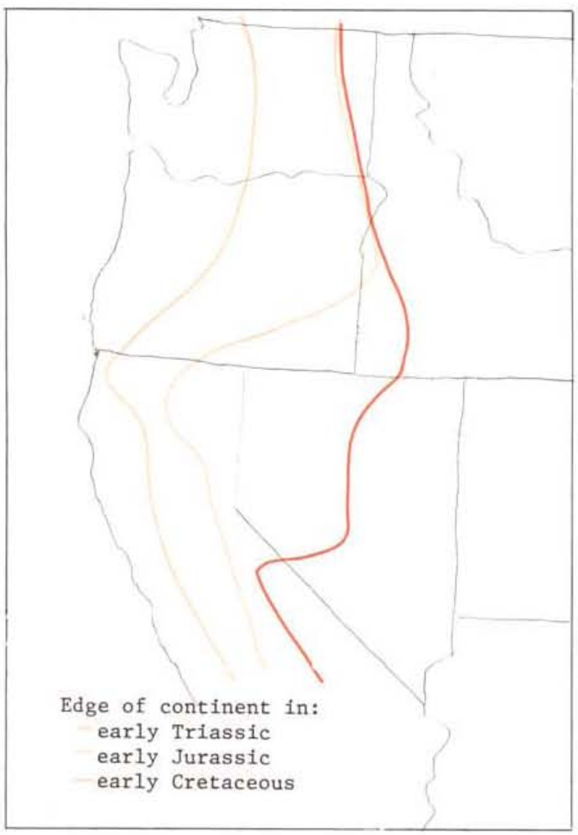


Figure 3. Map showing locations of continental margin at different times during the Mesozoic.

Figure 4. (opposite page) Geologic map showing areal distribution of pre-Cenozoic oceanic crust, volcanic arc and forearc basin terranes, and late Mesozoic plutons in Blue Mountains. Lines A-A' and B-B' show approximate locations of cross sections in Figure 5.

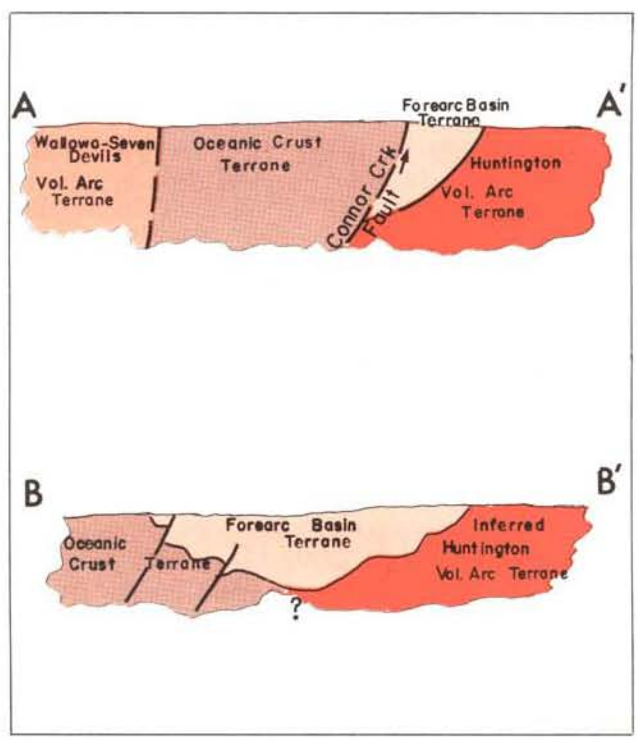
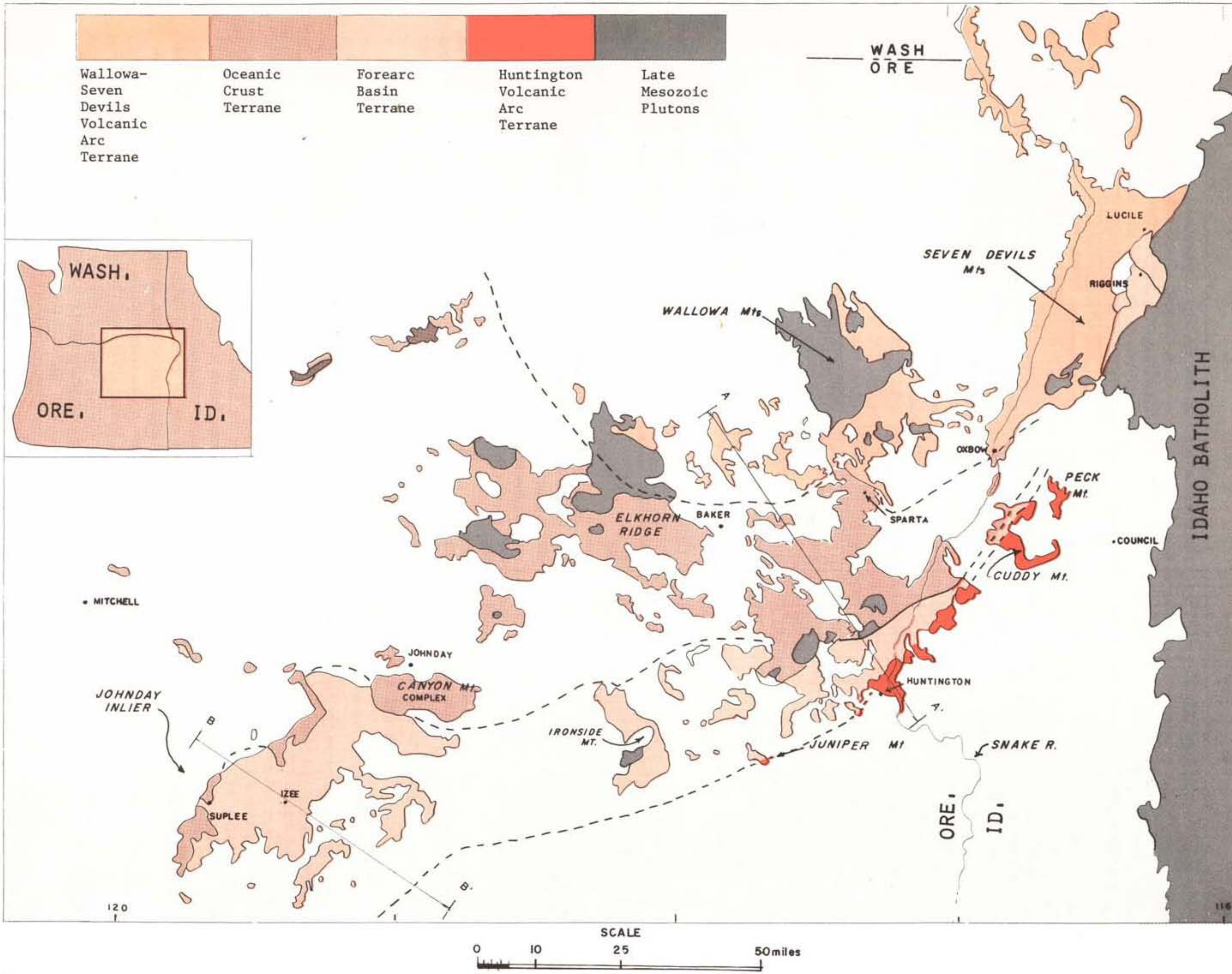


Figure 5. Schematic cross sections illustrating the inferred relationships between the terranes in Figure 4. See Figure 4 for location of lines A-A' and B-B'. Cenozoic cover and Mesozoic plutons are not shown.


Wallowa-Seven Devils Volcanic Arc Terrane
Oceanic Crust Terrane
Forearc Basin Terrane
Huntington Volcanic Arc Terrane
Late Mesozoic Plutons
WASH
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ORE.
ID.
SEVEN DEVILS Mts
WALLOWA Mts
LUCILE
RIGGINS
IDAHO BATHOLITH
OXBOW
PECK Mt.
SPARTA
BAKER
ELKHORN RIDGE
COUNCIL
CUDDY Mt.
MITCHELL
JOHNDAY
CANYON Mt. COMPLEX
JOHNDAY INLIER
HUNTINGTON
IRONSIDE MT.
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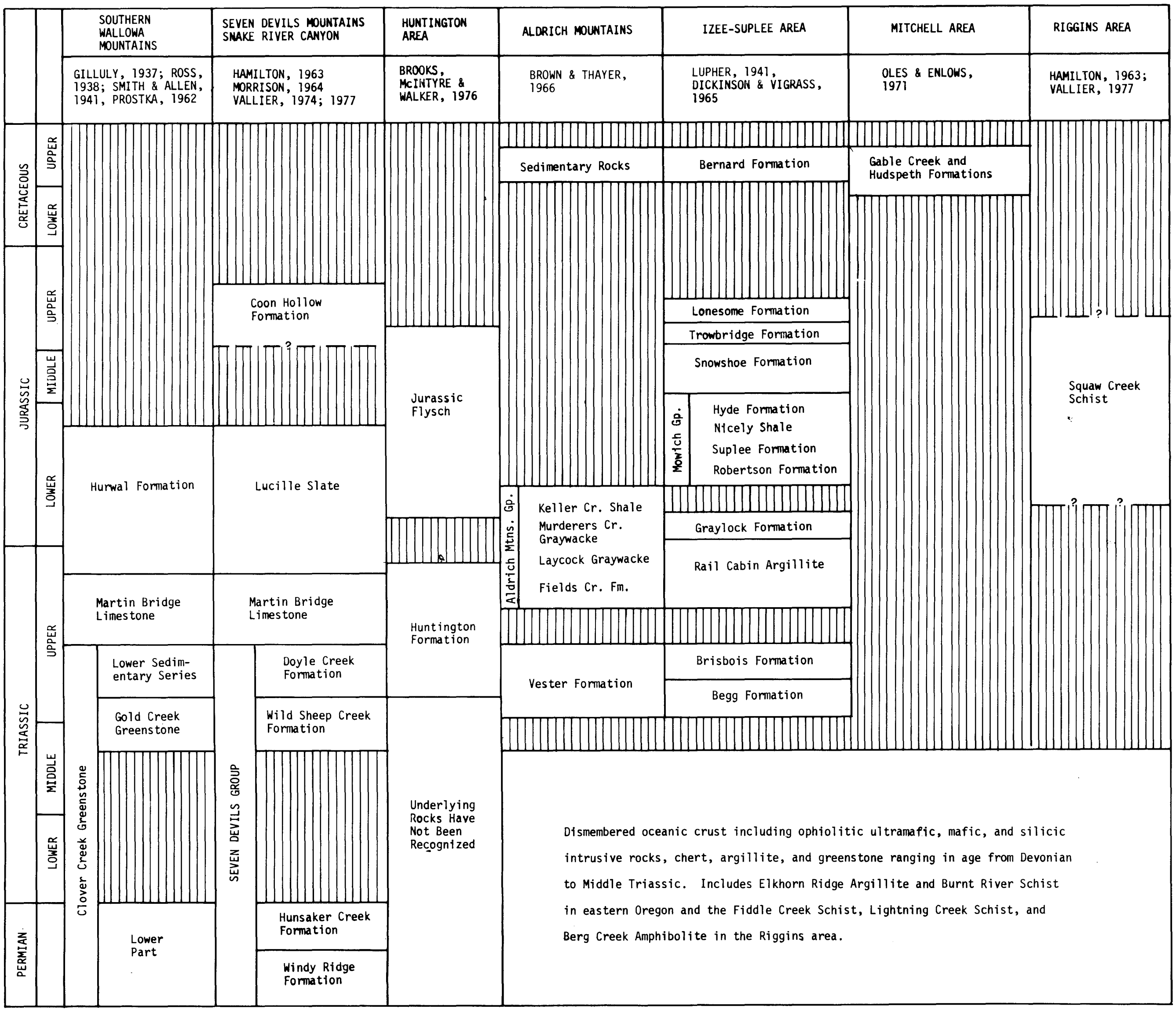

Figure 6. Mesozoic correlation chart for key Blue Mountains areas.

The relationship between the Huntington arc terrane and the Wallowa-Seven Devils volcanic arc terrane is not clear. The contact between the two is buried beneath Cenozoic lavas south of the Seven Devils Mountains. They may be parts of the same volcanic arc or parts of different, possibly widely separated, arcs brought close together by plate movements.

Forearc basin terrane

The forearc basin terrane is represented by a great thickness of mainly clastic strata between the dismembered oceanic crust terrane and the Huntington arc terrane. Rocks of the forearc basin conceal the contact between the oceanic and arc terranes (Figure 5). Deposition occurred in Late Triassic to Late Jurassic time. The strata have an aggregate thickness of 15,000 m. Dominant rock types are sandstone, siltstone, shale, and tuff, with subordinate lava flows and scattered limestone and conglomerate beds. Most of the clastic rocks are made up largely of detritus eroded from volcanic rocks; some consist mainly of chert grains, and some consist of water-laid tuff.

In the Snake River area, Lower Jurassic beds of the forearc basin terrane rest unconformably on the Upper Triassic volcanic rocks of the Huntington arc terrane and are in contact with rocks of the dismembered oceanic crust terrane along the Connor Creek fault. These rocks comprise the "flysch terrane" of Brooks and Vallier (1978) and the "Jurassic flysch" of Figure 6. The term "flysch" is used in its broad sense, to mean an extensive sedimentary formation derived by rapid erosion of an adjacent rising land mass.

A conglomeratic unit at the base of the flysch is made up largely of rounded fragments of volcanic rocks eroded from emergent parts of the Huntington arc terrane and deposited on its submerged flanks. Some of the rocks contain fragments of granitic rocks from the plutonic core of the volcanic arc. The much thicker sequence of sandstone and siltstone overlying the conglomerate represents deposition of finer grained erosional debris that was transported farther from shore.

The presence of erosional and tectonic fragments of oceanic rocks in the flysch indicates that rocks of the oceanic crust terrane formed the north wall of the basin in which the flysch was deposited. The Connor Creek fault is a high-angle reverse fault along which rocks of the oceanic crust terrane have been uplifted and shoved southeastward over part of the flysch. The attitude of the fault and the shear cleavage in the flysch are approximately parallel, suggesting that movement on the fault and deformation of the flysch were related and involved compression of the flysch against the Huntington arc.

The southwestern portion of the forearc basin terrane south and southwest of John Day is commonly called the John Day inlier. Mesozoic clastic rocks in that area are only weakly metamorphosed and not greatly deformed. Consequently, a wealth of stratigraphic detail has been developed. Fossils have been collected from hundreds of localities in Mesozoic strata for which about 25 formal stratigraphic names are currently valid. At least six unconformities break the stratigraphic sequence, and many of the units are thin and have limited lateral extent. Stratigraphic columns for the Aldrich Mountains and Izee-Suplee areas of the inlier are shown in Figure 6.

Most of the Mesozoic sandstones throughout the inlier contain sedimentary detritus from rocks typical of volcanic island arcs. A likely source for some of the volcanic detritus is the Huntington volcanic arc. The Huntington arc terrane is not exposed southwest of Juniper Mountain (Figure 4), but a southwestward extension of it is inferred to exist beneath Tertiary rocks southeast of the John Day inlier. High in the sequence are water-laid tuffs that are younger than any dated rocks in the Huntington arc terrane, indicating that there were additional volcanic sources. Some of the Upper Triassic rocks in the lower part of the sequence were deposited on rocks of the oceanic crust terrane, from which the sediments were in part derived. Rocks in the middle and upper levels of the sequence are made up largely of detritus derived from the kinds of rocks which are typical of volcanic island arcs. The occurrence of lava flows and other products of active volcanoes in places within the John Day inlier indicates that active volcanoes were not far away.

CONCLUSIONS

The oceanic crust and island arc terranes exposed in the Blue Mountains were accreted to the continent between Late Triassic and Middle Cretaceous times. Present indications are that both volcanic arc terranes are of intra-oceanic origin and therefore could not have been accreted to the continent until after the youngest associated rocks were deposited. The youngest dated rocks in the Huntington arc terrane are of Late Triassic (Norian) age. The youngest rocks in the Wallowa-Seven Devils arc terrane are clastic strata of Early Jurassic (Pliensbachian) age.

Mid-Cretaceous sedimentary rocks in the western part of the province contain erosional debris from the oceanic crust and forearc basin assemblages and from Mesozoic plutons and are therefore believed to have been deposited after the older terranes became attached to the continent. Clearly all the pre-Cenozoic terranes had been deeply eroded prior to the deposition of the oldest continental volcanic and sedimentary rocks in early Tertiary time.

The pre-Cenozoic rock assemblages in the Blue Mountains represent small parts of a very large plate tectonics jigsaw puzzle that can never be entirely reconstructed because some of the pieces are missing or are obscured by younger rocks and tectonic events. Some of the major questions remaining to be answered involve the identification of the substructure of the arc terranes, determination of the structural relationships between the oceanic crust and island arc terranes, and resolution of the problem of whether the two arc terranes are parts of the same arc or juxtaposed fragments of different arcs.

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AMENDED OIL AND GAS RULES

Amended Oil and Gas rules are in the process of being printed at the Secretary of State's office but will not be available for at least several weeks. Therefore the Oregon Department of Geology and Mineral Industries has had the amended rules printed and is circulating them so they may be referred to in the interim. These amendments are available from the Department's Portland office for $0.75 to cover the cost of handling and mailing.

The amendments, plus the existing rules, comprise a complete set of oil and gas regulations. □

ABSTRACTS

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

STRATIGRAPHY AND PETROGRAPHY OF THE SELAH MEMBER OF THE ELLENSBURG FORMATION IN SOUTH-CENTRAL WASHINGTON AND NORTH-CENTRAL OREGON, by Mavis Hensley Kent (M.S. in Geology, Portland State University, 1978)

The Selah Member of the Ellensburg Formation is a sedimentary interbed within lava flows of Yakima Basalt and occurs in south-central Washington and north-central Oregon. The Selah Member is overlain by the Pomona Member of the Saddle Mountains Basalt and underlain by the Priest Rapids Member of the Wanapum Basalt. The Selah Member has been studied in detail within the southwestern portion of the Columbia Plateau, in the Roosevelt-Arlington basin, an east-west trending structure which parallels the axis of the Dalles-Umatilla syncline. The Roosevelt-Arlington basin is bounded by the Horse Heaven Hills anticline to the north, and the Willow Creek monocline to the south.

Within the Roosevelt-Arlington basin the Selah Member is divided into three lithologic and petrographic units. The lowermost unit, I, consists of air-fall tuff, accretionary lapilli tuff, pumicite, and minor volcanic litharenite and siltstone. The middle unit, II, is subdivided into: (1) a northern part consisting primarily of volcanic lith-arenite, feldspathic volcanic lith-arenite and basaltic conglomerate, which is referred to as the tectonic facies; and (2) a southern part consisting primarily of claystone and siltstone, referred to as the lacustrine facies. The uppermost unit, III, consists of water-lain siltstone, volcanic lith-arenite, vitric (volcanic) lith-arenite, and minor pumicite and accretionary lapilli tuff.

The light mineral assemblage (<sp gr 2.96) in the Selah member consists of altered vitric (devitrified ash) rock fragments (up to 99.8 percent by volume), sanidine feldspar, glass, plagioclase feldspar, and quartz, and indicates abundant primary volcanic air-fall sources. The heavy mineral assemblage (>sp gr 2.96) consists of opaques, hypersthene, hornblende, basaltic hornblende, clinozoisite, epidote, topaz, and zircon, and also indicates a primary volcanic source. Plutonic/metamorphic minerals comprise less than 5 percent of the heavy mineral assemblage, and commonly less than 0.5 percent of the total mineral volume.

Explosive volcanic activity during Selah time, probably in the Cascade Range to the west, was a major source of the tephra that were deposited in streams and shallow lakes within the Roosevelt-Arlington basin. Penecontemporaneous deformation during Selah-time, probably associated with the major structural features bounding the Roosevelt-Arlington basin, is suggested by the presence of basaltic conglomerates and an erosional unconformity at the base of unit II-tectonic facies. The absence of the ancient Columbia River in the Roosevelt-Arlington basin during deposition of the Selah Member is indicated by the structural and/or topographic isolation of the Roosevelt-Arlington basin, the lack of quartzitic gravels, and the low volume of plutonic/metamorphic sediments. It is suggested that the Columbia River occupied a northerly course during deposition of the Selah Member.

THE STRATIGRAPHY AND STRUCTURE OF THE COLUMBIA RIVER BASALT IN THE CLACKAMAS RIVER DRAINAGE, by James Lee Anderson (M.S. in Geology, Portland State University, 1978)

The Clackamas River drainage within the western Cascade Range is approximately aligned with a northwest trending lineation defined by the Portland Hills and the Brothers Fault zone. This area is occupied by an extensive Columbia River Basalt sequence that is deeply incised by the Clackamas River and its tributaries. Two major basalt units of the Yakima Basalt Subgroup, including the Grande Ronde Basalt and the Frenchman Springs Member of the Wanapum Basalt, are distinguishable in a 515 m to 550 m accumulation. Of particular interest is the presence of five distinct geochemical and paleomagnetic subunits within the Grande Ronde Basalt. These include, from oldest to youngest, the paleomagnetically normal (N_1) low Mg0, reversed (R_2) low Mg0, reversed (R_2) Prineville, normal (N_2) low Mg0, and normal (N_2) high Mg0 geochemical types. Interbeds having wide lateral extent and ranging in thickness from 3 to 35 m are numerous, indicating close proximity to a degrading highland. Composition of these units indicates contemporaneous Cascadian volcanism.

The structural grain of the area is primarily northwest with lesser northeast and north-south components. A general northwest dip of less than 10° predominates and reflects Cascadian uplift. Northwest faults cut the shallowly dipping Columbia River Basalt sequence in an en echelon pattern that is distributed across the entire area. Sense and magnitude of movement on all faults are highly varied. Both strike-slip and dip-slip faulting have been recognized, with the throw on normal faults commonly ranging between 100 and 200 m. Graben structures are defined by faults in both the Fish Creek Airstrip and Roaring River areas. The basalt is most deformed along the northeast margin of the area where dips of 10° to 35° occur. An anticlinal fold is indicated by attitudes in the Roaring River area. Folding over the rest of the Clackamas River study area is of a very broad nature. Vertical fault planes, orientation of structures, and the presence of northwest trending right-lateral strike-slip faults are consistent with a stress model of north-south compresion and east-west extension. □

meeting announcements

Each month, space permitting, upcoming meetings will be announced in this column. Information should reach this office no later than six weeks before a meeting. Please be specific and give full name of the organization; exact subject, location, and time of the meeting; and the name, address, and phone number of person to contact for questions or reservations.

NATIONAL AEG PRESIDENT TO SPEAK

The Oregon section of the Association of Engineering Geologists will meet Thursday, May 17, at the Tualatin Ramada Inn (I-5 at the SW Nyberg Road exit). Underground tunneling will be the subject of the evening's talk by national AEG president Richard J. Proctor, Metropolitan Water District, Los Angeles, California. Social hour will be at 6:00 p.m., dinner at 7:00, and meeting at 8:00. For more information about the meeting, call Mavis Kent (635-4419). For dinner reservations, call Lew Gustafson (221-6460) or Jack Richards (221-3867).

GSOC LUNCHEON TALKS ANNOUNCED

The Geological Society of the Oregon Country holds noon luncheon meetings on the first and third Fridays of each month in Room A, adjacent to the cafeteria, third floor, Standard Plaza, 1100 SW 6th Avenue, Portland. Upcoming topics and speakers include:

May 18: **ENERGY FOR THE FUTURE,** talk by Harry T. Moorefield, office supervisor, Portland region, Atlantic Richfield Co.

June 1: **SANDY RIVER GORGE,** talk by Tom McAllister, Outdoor Editor, Oregon Journal.

June 15: **SOUTHEAST RELIEVING SEWER: EAST PORTLAND,** talk by Robert L. Gamer, Senior Geologist, Foundation Sciences, Inc.

For additional information, contact Viola Oberson, Program Chairman (282-3685). The meetings are open to the public. No reservations are required. □

"You'd better make a decision soon. The continents are starting to drift apart."

(C) Punch-ROTHCO

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COVER PHOTO

Oregon's first "Christmas tree," Reichhold's Columbia County No. 1, located near Mist, Oregon. The assembly of pipes and valves on the top of this successful gas well will control the flow of gas from the well. See story beginning on the next page.

Sixth Gold and Money Proceedings released

The Oregon Department of Geology and Mineral Industries now has available copies of the *Proceedings* of the Sixth Gold and Money Conference, held May 1978 in Portland. This publication contains several papers on the world monetary situation as well as technical papers on current heap leaching methods and on operations at gold mines in Nevada and Oregon.

Copies may be obtained from the Portland office of the Oregon Department of Geology and Mineral Industries. Price is $6.50 postpaid, and checks should be made payable to **Gold and Money Session.** □

Department geothermal specialist attends workshop

Joseph F. Riccio, Geothermal Specialist with the Department, attended a workshop on "Application of Heat Flow and Geothermal Gradient Techniques to Geothermal Exploration" April 29-May 3, 1979. The U.S. Geological Survey Geothermal Research Program sponsored the workshop, which was organized by Southern Methodist University and held at the Fort Burgwin Research Center, Taos, New Mexico.

Fifty-one participants representing industry, government agencies, universities, and research laboratories attended. Meetings were chaired by David Blackwell, Southern Methodist University, and Donald Klick, Extramural Geothermal Research Branch of the U.S. Geological Survey.

Research items covered by individual papers and discussions included: "Basic Heat Flow and Geothermal Gradient Exploration Techniques," "Heat Flow and Geothermal Gradient Techniques in Deep and Shallow Holes," "Interpretation of Conduction and Convection Techniques," and "Regional and Local Case Histories."

A field trip to the Jemez Mountains to view the results and progress of Union Oil Company's Redondo Peak geothermal prospect concluded the workshop. □

CONTENTS

Oregon's first gas wells completed

by Vernon C. Newton, Jr., Petroleum Engineer, Oregon Department of Geology and Mineral Industries

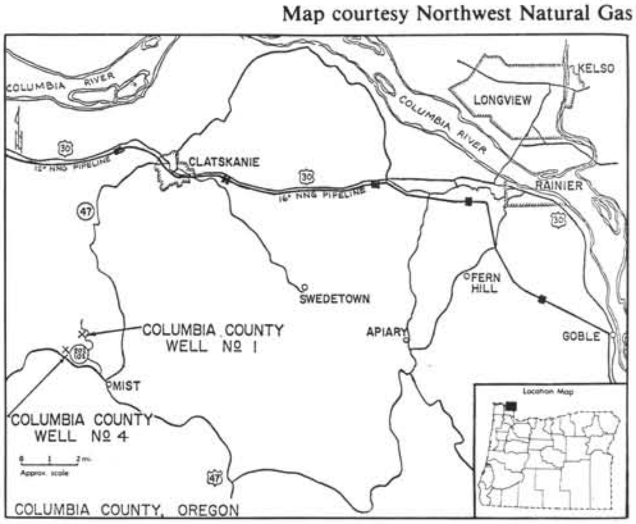
On May 2, 1979, Governor Victor Atiyeh announced the completion of an exploratory natural gas well in SE¼NW¼ sec. 11, T. 6 N., R. 5 W., Columbia County, near the town of Mist, Oregon. Reichhold Energy Corporation's Columbia County No. 1 flowed an estimated 2 million cu ft per day on test, making it Oregon's first commercial natural gas well. The discovery marks the end of a four-year search by Reichhold. On May 14, Columbia County No. 4, a second well half a mile away, was tested and appeared to be as successful as the first well.

Reichhold Energy Corporation was the operator of the wells; Northwest Natural Gas Company, Portland, Oregon, and Diamond Shamrock Company, Cleveland, Ohio, were partners.

The first oil and gas exploration well in Oregon was put down near the town of Newberg in 1901. Since then, more than 200 dry exploration holes have been drilled in the state. Pressure recovery following the flow test on Columbia County No. 1 was very rapid, indicating good reservoir characteristics. These data, however, do not provide conclusive information for determining the extent of the reserves of natural gas which may be available in the area.

When Columbia County No. 1 was first drilled by Reichhold and Diamond Shamrock in 1978, there was a minimal show of natural gas. When the hole was redrilled in May 1979, it was directed toward a more favorable location. A formation test indicated that the zone was commercial, so casing was run into the well, and the well was completed with production tubing on May 1, 1979.

Map courtesy Northwest Natural Gas

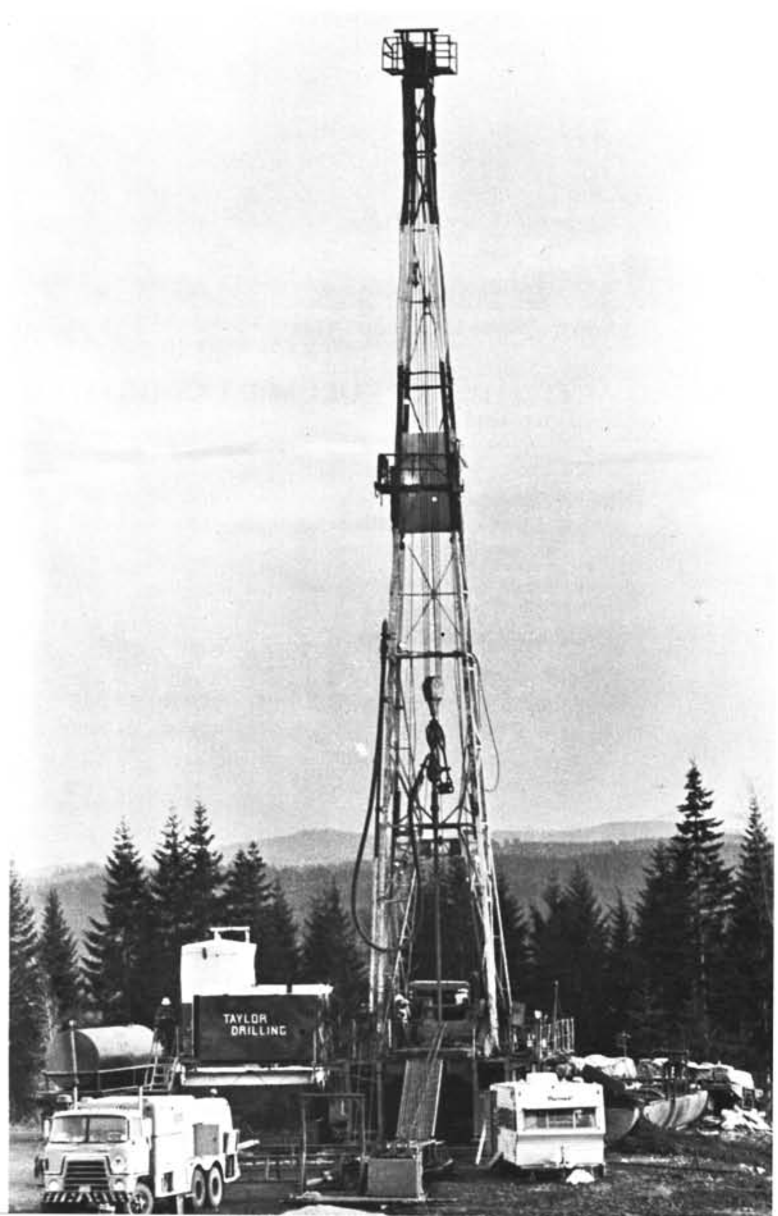


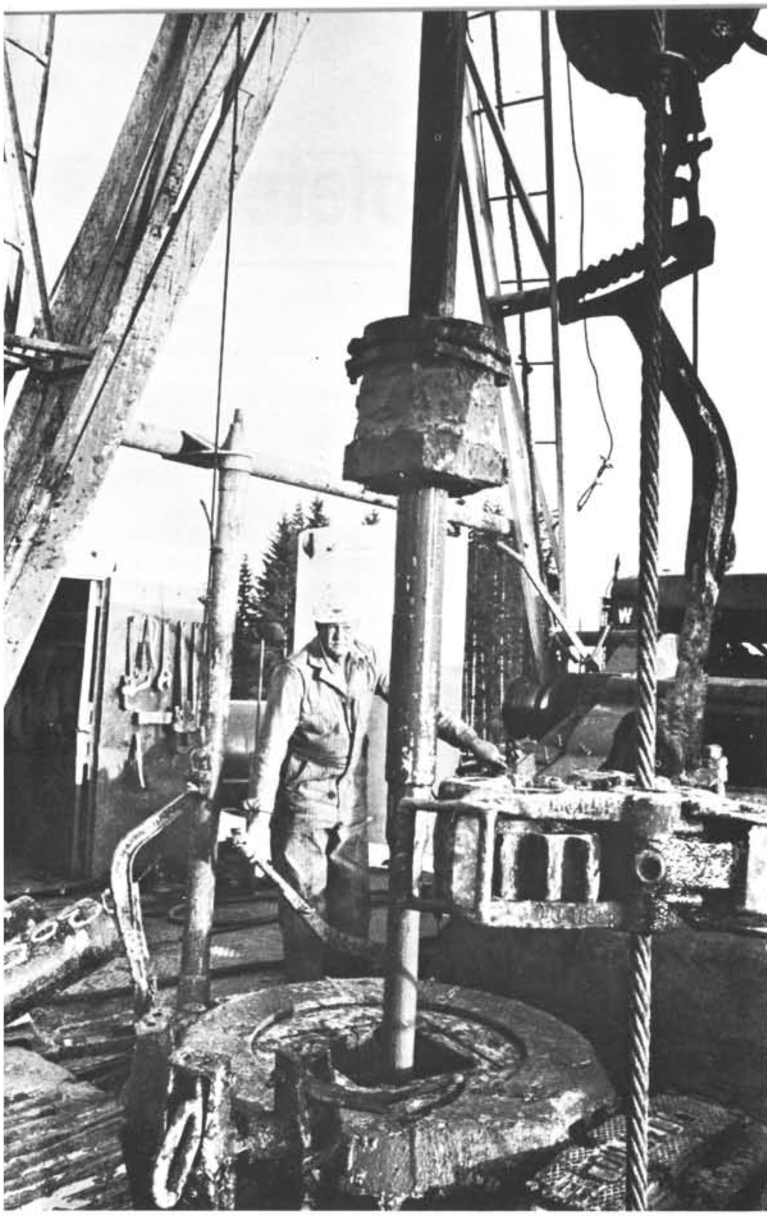
While the flows from these first wells are considered to be acceptable amounts, additional wells will be required to establish the extent of the reservoir and its adequacy for commercial production.

Reichhold Energy, the operator for the group, hopes to use part of the gas developed in the Mist area in its ammonia-urea plant located near St. Helens, Oregon. This plant uses natural gas as a chemical feedstock. Northwest Natural Gas will utilize its share of any gas produced at Mist to supplement its existing supply, but the impact on its operations cannot be determined at this time.

As the discovery well name indicates, Columbia County is the owner of minerals on the land containing

Columbia County No. 1, Oregon's first gas well.





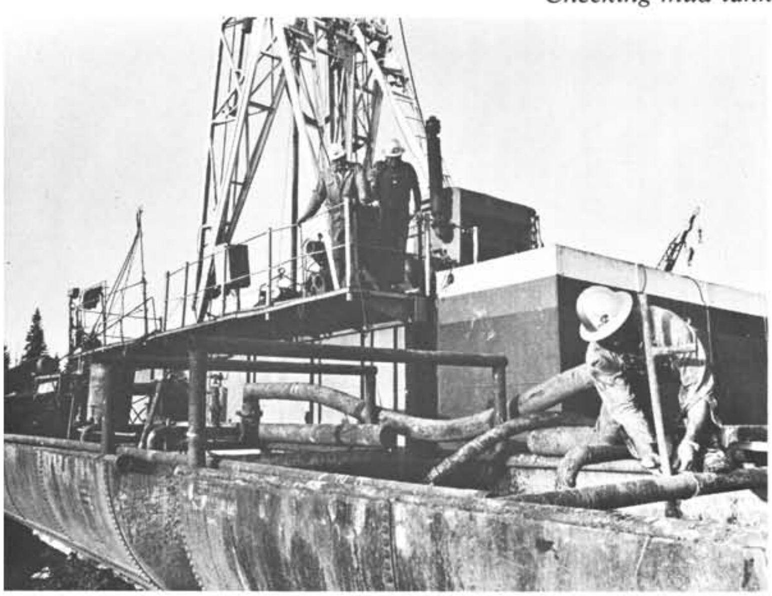
Pulling the kelly to add drill pipe.

Adding "gel" to drilling mud.

DRILLING ACTIVITIES AT COLUMBIA COUNTY NO. 1

Photos courtesy Northwest Natural Gas

Checking mud tanks.



Circulating mud prior to running logs.

Columbia County No. 1 wellhead pressure.

Vern Newton, Petroleum Engineer, Oregon Department of Geology and Mineral Industries, checking pressure gauge on first discovery gas well in Oregon.

Vern Newton, Oregon Department of Geology and Mineral Industries, and Tex Patterson, Drilling Superintendent, Reichhold Energy Corporation, discussing plans for Columbia County No. 4.

Derrick was lowered to ground after successful drilling of Columbia County No. 1 so it could be moved to next drilling site.

Derrick from Columbia County No. 1 being hoisted onto truck so it can be used in drilling Columbia County No. 4.

Additional well data from Columbia County No. 1		
Natural gas formation depth	Approximately 2,400 ft	
Flow tests	1,629,000 cu ft per day through a restricted orifice, flowing pressure 800 psig	
Static pressure	895 psig	
Gas composition	Nitrogen	6.9 %
	Methane	92.8 %
	Carbon dioxide	.03%
	Butane	.26%
Heating value	946 BTU per cu ft	

the well. Royalties from production will go to the county government and thus be a benefit to local citizens. Longview Fibre Company and Crown Zellerbach Corporation are owners of the surface property around the well and also mineral owners on some of the nearby leases. As gas wells probably will be spaced one per 160 acres, surface disturbance caused by field development will be minimal. Access to wells can be provided by existing logging roads.

Cartoon courtesy Art Bemrose, *The Sunday Oregonian*

The number of exploratory oil and gas wells drilled in Oregon translates into approximately one well per 400 sq mi. The search is just beginning.

Photo courtesy Northwest Natural Gas

Owner Al Cavanaugh stands outside Mist General Store, center of much activity resulting from successful drilling of gas wells near Mist.

Geologic mapping was done in northwestern Oregon by J.S. Diller in 1896. More detailed mapping was done later by C.E. Weaver (1937); W.C. Warren, H. Norbisrath, and R.M. Grivetti (1945); and R.O. Van Atta (1971). The Oregon Department of Geology and Mineral Industries extended geologic mapping of the area in 1975, outlining prospects for natural gas production and underground storage of pipeline gas in the Department's Oil and Gas Investigation No. 5, *Prospects for Natural Gas Production and Underground Storage of Pipeline Gas in the Upper Nehalem River Basin, Columbia-Clatsop Counties, Oregon.*

Rocks exposed at the surface in Columbia County range in age from Pliocene to upper Eocene. Miocene basalt is found in the eastern portion of the county. Marine sedimentary rocks underlie the lavas in this area to depths of 8,000 to 10,000 ft. Thus far, exploration drilling has shown that the best reservoir sands occur in the upper Eocene Cowlitz Formation.

The first drilling in the county was done by Texaco, Inc. In 1945, this firm put down two deep test holes, one south of the town of Clatskanie, and the other near the community of Mist. It was the findings in the Mist well that encouraged additional mapping in Columbia County and the eventual drilling program by Reichhold.

Results in the next few test holes will reveal more data regarding the size and extent of the new gas field. An increase in leasing activity has already begun, however, and news that Oregon will very likely join ranks with producing states is spreading. □

The Western Gold Dredging Company of John Day, Oregon

by John T. Leethem, geology student, Oregon State University

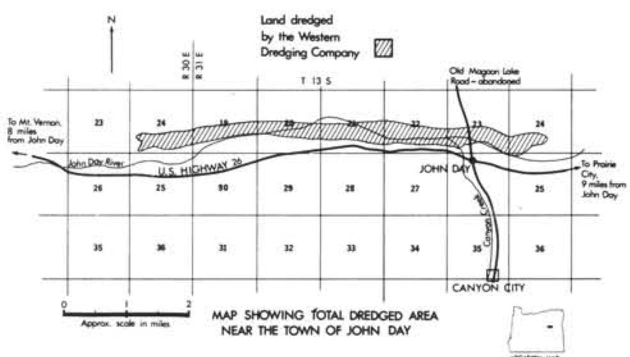
Author's note: The following article is an attempt by the author to preserve a part of Oregon's colorful history on gold dredging. It is the result of research and a series of four interviews with Ted Styskel, whose father was one of the owners of the dredging company. I am greatly indebted to him for his help and insight. Also, I would like to thank Howard C. Brooks, Oregon Department of Geology and Mineral Industries, for reviewing the article.

In 1934, Congress increased the price of gold from \$20.67 to \$35.00 per ounce, touching off renewed interest in gold dredging. In 1936, the Consolidated Western Dredging Company of John Day began exploration. The company was formed during the depression, when S.P. Lowengart, E.C. Styskel, and Ben Ettelson incorporated and invested in a dredge. Initial investment for prospecting, land, and equipment came to about half a million dollars. The men purchased mineral rights along the John Day River, and the dredge was set up near the city limits of John Day.

Production began in November 1937 near the confluence of the John Day River and Canyon Creek. Soon after, the name of the company was changed to the Western Gold Dredging Company.

The area where dredging began was known as the Old China Diggings and was the richest land ever worked by the dredge. The China Claims were rich placer deposits which had been worked around the turn of the century by Chinese laborers using shovels, gold pans, rockers, and sluices. The early-day mining ventures had attracted the Chinese to John Day, where they had built their own little Chinatown.

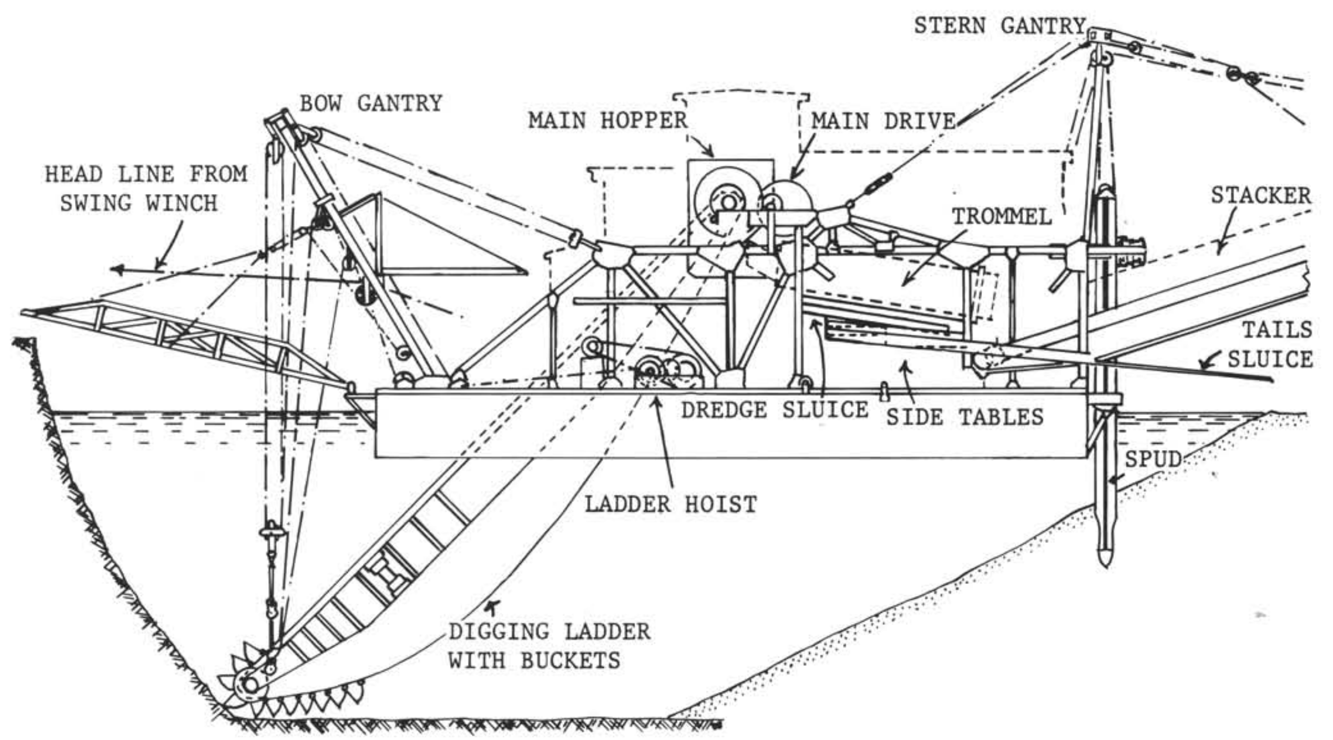
From the town of John Day, the dredge followed the John Day River west to the property of J.H. Ferris and J.W. Marchbank (NE¼ sec. 25, T. 13 S., R. 30 E.), roughly halfway between the towns of John Day and Mt. Vernon. Ferris and Marchbank were already operating a dragline dredge or "doodlebug" with a 4½-yd bucket and a floating washing plant that contained a hopper for receiving gravel dug by the dragline, a revolving screen, riffled sluices or a revolving pan amalgamator, and a tailings stacker.



From this point, the Western Gold Company dredge turned around and went east back to John Day, dredging just north of the earlier dredged land. When the dredge came to the place where the road crossed the river, it was stopped until an agreement was reached with the city to tear down the bridge, run the dredge through, and build a new bridge. Then the dredge followed the river east for about 1½ mi until it became unprofitable to operate. At that point, the dredge was dismantled and trucked to Mt. Vernon, 8 mi west of John Day.

The Western Gold Company dredge was of the bucket-line type. Each bucket had a capacity of 6 cu ft of gravel. Later, the bucket lips were redesigned to increase the capacity to 7 cu ft. The number of buckets used could be varied from 68 to 81, which also changed the depth the dredge could dig.

Front view of Western Gold Dredging Company's gold dredge, in operation on John Day River. Bucket line in front carried fluvial material into dredge. (Photo courtesy Ted Styskel)



Generalized side view of gold dredge. (After Peele, 1941)

During its operation, this dredge was the second largest in Oregon. It was three stories high, about 100 ft long, and powered by two 200-horsepower diesel engines. One engine ran direct drive to the bucket line, and the other ran a generator that powered the pumps and winches.

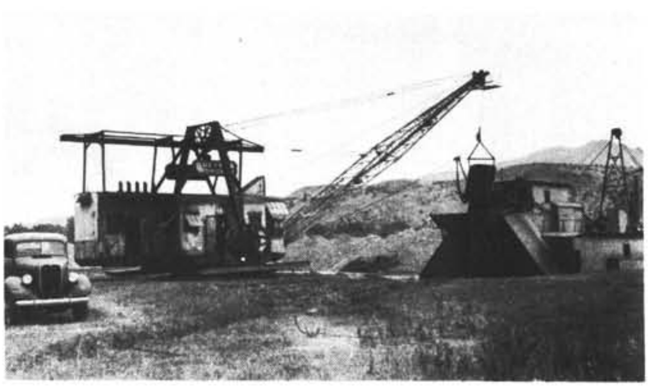
The dredge was secured to the shore by cables attached to deadmen or pilings. These cables were on winches. To move the dredge, the winchman would simultaneously tighten one cable and loosen the other. When the dredge was digging, a huge counterweight called a spud was sunk down to the bed rock to provide a pivot for the boat to turn on. The boat required a large source of water in order to operate. Because the dredge virtually dug its own channel as it worked its way through the river deposits, it has often been said, "Where the dredge goes, the river follows."

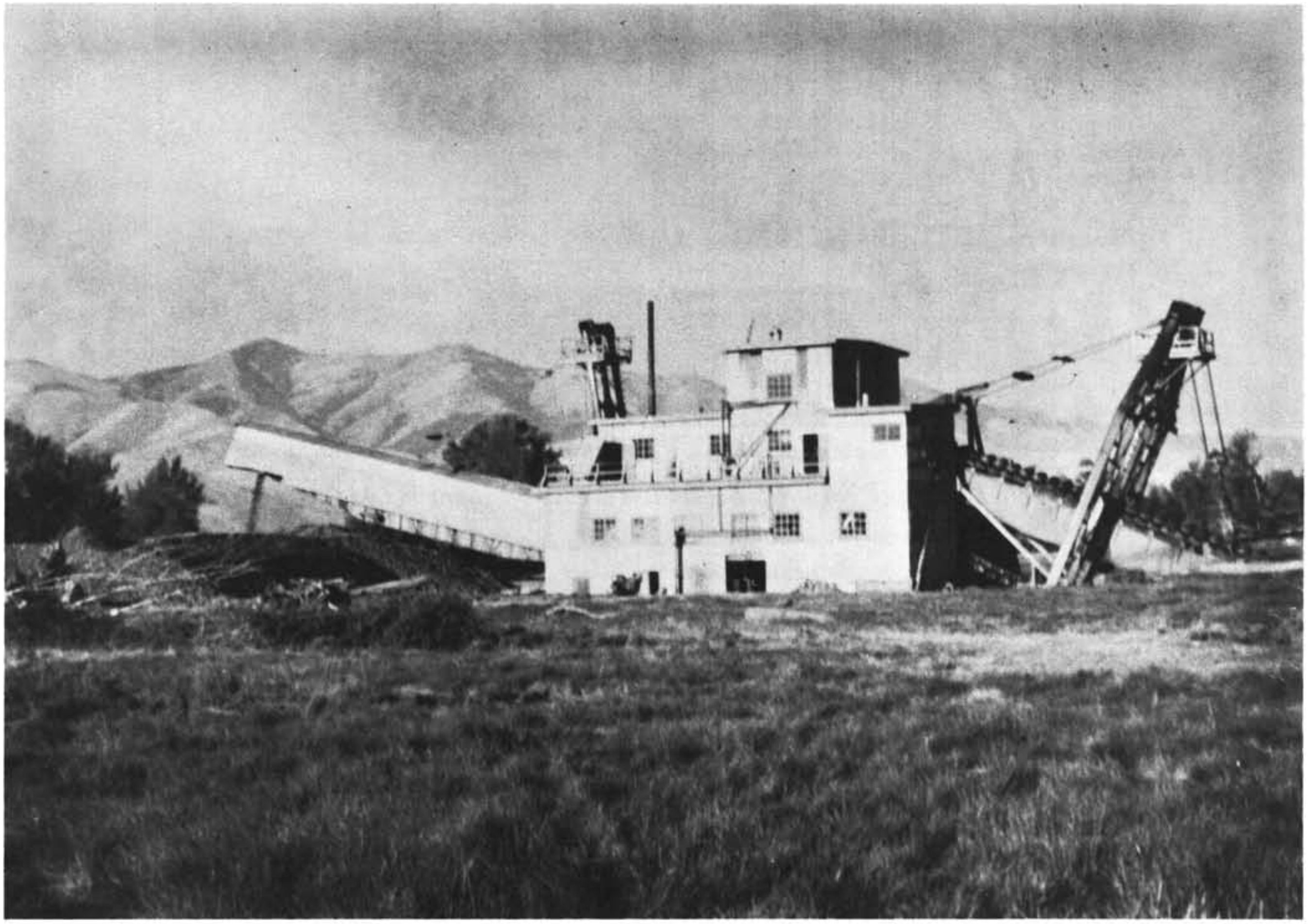
The buckets were continually dumping the fluvial deposits into a revolving screen called a trommel while water from spray nozzles washed the finer material through holes in the trommel. From the lower end of the trommel, boulders and coarse gravel were taken on a stacker (conveyor belt) and dumped in piles behind the dredge.

The finer gravel and silt that washed through the trommel ran over the dredge sluices. A sluice is a long, sloping table over which placer gravel is carried by a stream of water. The dredge sluices had a thin layer of liquid mercury on top of mats. When gold or silver went over the sluices, it amalgamated or alloyed with the mercury. Because these first tables recovered 90 percent of the gold, they were locked up. The last 10 percent of the gold was recovered in sluices called side tables or tailings sluices. These were simply shallow troughs with steel grating over which water ran and gold accumulated behind riffles (transverse bars in a sluice or table to trap gold and other heavy minerals). Approximately every two weeks, the amalgam was washed out of the mats, and the riffles were cleaned.

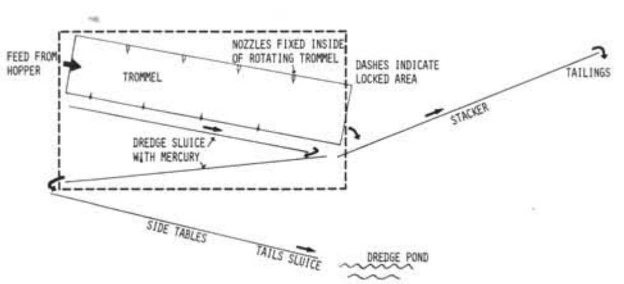
During the first several years of operation, heavy black sands were found along with the gold and silver. At first, they were thought to be worthless, so they were

Ferris and Marchbank operation, showing dragline and floating washing plant.

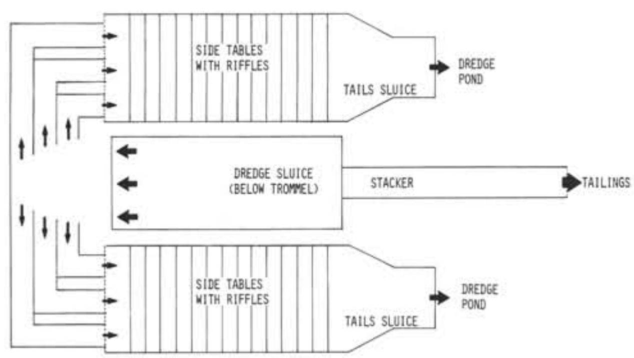




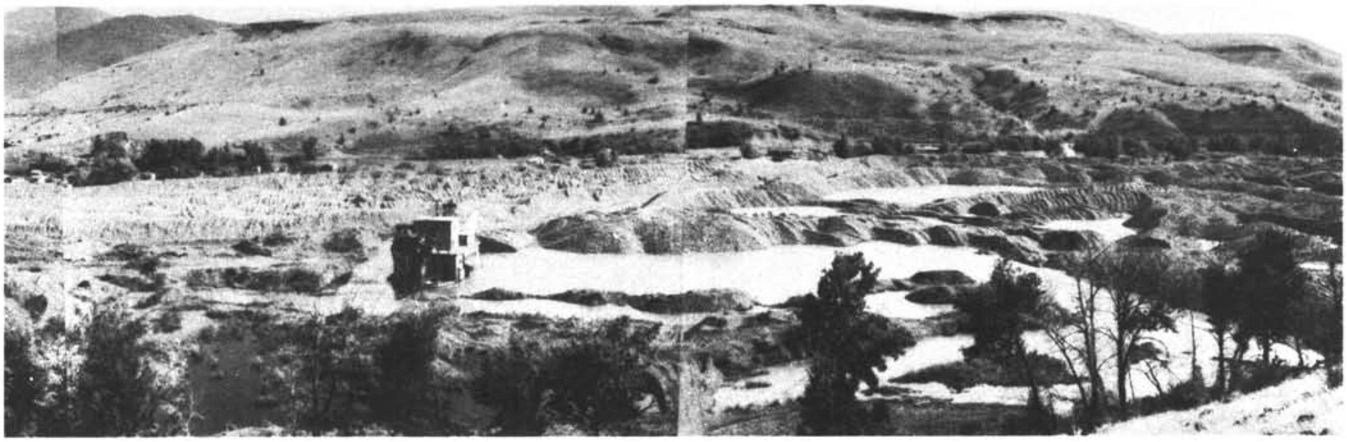
Side view of dredge in operation near town of John Day. Note coarse material deposited by stacker on tailings pile behind stern of dredge. (Photo courtesy Ted Styskel)



Side view of gold-saving equipment on gold dredge. Dashes indicate locked area. Material from stream bed was carried by buckets into hopper and from there was fed into trommel (revolving screen). Fine material washed through trommel onto dredge sluice below, where mercury on mats helped catch the gold, and then went to side tables, tails sluice, and dredge pond. Coarser material that did not fall through trommel was carried by stacker (conveyor belt) out to tailings pile.



Top view of gold-saving equipment. Material was washed onto dredge sluice from trommel and then onto riffled side tables. Then it flowed over tails sluice and into dredge pond.



Western Gold Dredging Company's bucket-line dredge operating in Old China Diggings.

Looking north across John Day today, where reclaimed dredged land is being used in variety of ways. John Day River is in background, at base of hills in line of trees. All flat area in middle ground was once dredged but is now being used as shopping center site, mobile home court, and State storage yard for heavy machinery and supplies. Airport was originally located on site of present-day mobile home court. (Photo courtesy Ted Styskel) discarded. When they were assayed, however, the assay showed the metals to be the platinum-group metals osmium and iridium, the heaviest naturally occurring substances known.

The recovered amalgam was taken to a retort house, where a propane furnace vaporized the mercury. The mercury vapor rose through tubes to a gooseneck with water jacket, where it was condensed and recovered. The gold sponge left after the mercury was driven off was heated in a different crucible, and the impurities came to the surface. The surface impurities were then poured off into a base bar, which contained gold, silver, and other substances. The remaining relatively pure gold was then poured into a bullion bar. Average cleanup every two weeks produced one bullion bar and one base bar. These bars were then taken for further refining to Selby, California, where the American Smelting and Refining Company further processed the gold for the U.S. Treasury Department.

When the Western Gold Dredging Company began operations, it was quite a buoying force in the local economy. The company employed about 25 men, and it acquired its land by buying mineral rights at $200 an acre from many farmers, thereby enabling some of them to keep their ranches during the depression.

In 1942, during World War II, legislation stopping all gold mining and dredging was passed. After the war, the company, renamed the Buffalo Gold Dredging Company, operated its dredge in 1948 and 1949 until it became uneconomical to continue. In 1950, the company was liquidated; in 1971, a Seattle scrap company cut up the dredge and hauled it away.

Since the time the land was dredged, most areas of the John Day Valley have been reclaimed. Flattened by bulldozers, dredged land is ideal for many uses because of its flatness and good drainage. Several cattle and sheep feedlots have been made on dredged ground by spreading sawdust on the earth. Alfalfa has been grown successfully on dredged land used for several years previously as a feedlot. Homes have been built on dredged ground because it provides good drainage and solid support for foundations. Gravel is easily quarried on the dredged ground by the State Highway Department for use on roads and by private firms for use in construction. The John Day airport was once located on the flat land but has since been moved. Dredged land along the John Day River has become the site of a trailer park, three sawmills, lumber drying yards, the Grant County High School, the city park, and a shopping center.

Persons wishing to see a gold dredge in Oregon may visit the Sumpter gold dredge, which today exists as a museum in Sumpter. Guided tours are conducted through it for a fee. For further information, contact Ray Barzee, Sumpter, Oregon 97877; phone: (503) 894-2311 or 894-2229.

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Sulfide mineralization reported in Benton County

by Jerry J. Gray, Economic Geologist,
Oregon Department of Geology and Mineral Industries

During the field surveying of stone quarries for the Department's Short Paper 27, *Rock Material Resources of Benton County, Oregon* (Schlicker, Gray, and Bela, 1978), field assistant Garwood Allen reported so much pyrite in stone-quarry sites 116 and 117 that he could smell it.

This author's curiosity was whetted, so he visited the sites and took grab samples in and between the two quarries. The major sulfide mineral giving the sulfur odor was identified as pyrrhotite (magnetic pyrite), which can range in composition from Fe_5S_6 to $Fe_{16}S_{17}$. The samples assayed gold, trace; copper, 60 ppm; zinc, 91 ppm; cobalt, 5 ppm; molybdenum, 3 ppm; nickel, 5 ppm; and mercury, 0.7 lb per ton. The two quarries are on the east end of a long, narrow dike of gabbro.

The outcrop and quarry walls are highly colored with yellow and brown from the oxidation of the pyrrhotite. Both quarries are in sec. 32, T. 13 S., R. 5 W. on Pigeon Butte, which is part of the William L. Finley National Refuge. The exact localities are shown on the map in Short Paper 27. The assay values of all metals assayed, particularly the gold, molybdenum, and mercury, appear to be anomalous. □

Columbia River Basalt bibliography completed

by James L. Bela, Environmental Geologist,
Oregon Department of Geology and Mineral Industries

Open-File Report 0-79-1, *Annotated Bibliography of the Geology of the Columbia Plateau (Columbia River Basalt) and Adjacent Areas of Oregon,* was released March 3, 1979. It contains approximately 2,000 entries and includes both a complete alphabetical listing and also a topical listing with 14 separate categories: pre-Plateau basalt geology, general geology of areas marginal to the Columbia Plateau in Oregon, basalt stratigraphy, basalt laboratory studies, post-Plateau basalt geology, geologic mapping, structural geology, seismicity and tectonics, geophysical studies, remote sensing studies, hydrologic studies, test wells, paleontological and archaeological findings, and mineral resources.

The bibliography was prepared by the Department of Geology and Mineral Industries as Subcontract SA-913 in partial fulfillment of the provisions of Contract Number EY-77-C-06-1030 with the U.S. Department of Energy. The contract is being administered through Rockwell Hanford Operations, Richland, Washington, as part of their Basalt Waste Isolation Program.

The objective of this program is to determine the feasibility of storing nuclear waste within the Columbia River Basalt Group, with special emphasis on the Pasco Basin in Washington. Under the geologic portion of this program, the stratigraphic, structural, tectonic, seismic, and hydrologic aspects of the Columbia Plateau are being examined. Other aspects of the Basalt Waste Isolation Program are concerned with systems integration, engineered barriers, engineering testing, and construction of a near-surface test facility.

Similar compilations for bibliographies of geologic and related studies of the Columbia Plateau in Washington and Idaho have been completed by the Washington State Department of Natural Resources (1978) and the Idaho Bureau of Mines and Geology (1978).

Comprehensive geologic information about the Hanford site in the Pasco Basin is needed for a proper evaluation of that area for nuclear waste disposal purposes. Although the basin is located in southeastern Washington, proper handling of some of the geologic issues requires additional geologic information from surrounding areas. Thus, basalt flows, Quaternary units, basement rocks, and structures which extend from the Pasco Basin into neighboring Oregon are properly understood only if geologic information and features in Oregon are addressed as part of the overall investigation. Furthermore, the delineation of other potentially favorable geologic sites within the Columbia River Basalt Group in Washington, Oregon, and Idaho is a major goal of the geologic mapping programs presently underway.

Accordingly, the Department of Geology and Mineral Industries prepared the bibliography to (1) serve as a research tool for later work in Oregon, (2) aid in the identification of problem areas in Oregon in need of further study, (3) function as part of the data base for the Columbia Plateau, and (4) function as a first step in the generation of various Oregon Index Maps.

A similar program at another U.S. Department of Energy site in Nevada is evaluating the feasibility of storing nuclear waste within granite, shale, and tuff. In addition, a test facility in a salt formation near Carlsbad, New Mexico, is also being studied.

The open-file report is not for sale but is available for inspection at the Oregon Department of Geology and Mineral Industries in Portland and in field offices located in Grants Pass, Albany, and Baker. □

Oregon's rock material economic demand model—a progress report

by Jerry J. Gray, Economic Geologist,
Oregon Department of Geology and Mineral Industries

On a statewide basis, the Department recognizes the need to establish an inventory data base for rock materials, because the resource is being lost to urban growth and inconsistent zoning. Several countywide and one substate area inventory studies have already been completed by the Department.

Department inventory data along with data taken from the completed studies and used as a statistical sample of the entire state suggest that Oregon has 12,000 to 15,000 pits and quarries, of which 3,000 to 4,000 are active in any 12-month period. Annual output from these mines ranges from 30 to 50 million tons.

As land planning laws are passed and placed into effect, the need for rock resource assessments is becoming more acute. This need is formalized by ORS 215.055 and through Land Conservation and Development Commission (LCDC) Goal 5, Topic B, both of which formally direct counties and cities to take into consideration lands that are, can, or should be utilized for material sources or for the processing of mineral aggregates in the adoption of any land use ordinance.

Inventorying of rock material supply addresses only one-half of the problem. The amount of material needed today and in the future should also be known. In this way, supply and demand can be considered in making land use decisions. Under LCDC Goal 9, Guideline A-2, demand is recognized in the statement that, "The economic development projections and the comprehensive plan which is drawn from the projections should take into account the availability of the necessary natural resources to support the expanded industrial development and associated populations. The plan should also take into account the social, environmental, energy, and economic impacts upon the resident population."

Funding for the current study was obtained in August 1978 from the Army Corps of Engineers and the Northwest Regional Commission. The Department then invited proposals from the private sector to prepare economic demand forecasts for the entire state and for the several substate areas to show the need for mineral aggregate (sand and gravel and crushed stone) in Oregon for the next five, ten, and fifty years. Economic Consultants Oregon, Ltd., (ECO) of Eugene was the successful bidder. The study was started in November 1978. The purpose of the study was to produce:

1. Projections of demand for state and substate areas for five, ten, and fifty years in the future for (a) sand and gravel and (b) stone, based on end-use modeling for each commodity.
2. Appendices presenting production data and explaining the development of the forecasting model or models.
3. An explanatory text setting forth procedures and conclusions in terms understandable to well-informed planners and including properly qualifying data, assumptions, and conclusions.

Progress to date includes the development of two kinds of models by commodities, a growth-rate model and an econometric model. The substate areas that were chosen for demand modeling were:

1. Portland metropolitan area (Clackamas, Columbia, Multnomah, and Washington Counties)
2. Umatilla County
3. Medford-Ashland metropolitan area of Jackson County
4. Lincoln County
5. Willamette National Forest

These substate areas were chosen to fit a full range of economic and geographic market types. It was reasoned that appropriate models could then be picked as examples for any other part of the state.

Several interesting problems and relationships have surfaced during this model building. Some of them are:

1. The inadequacies of data available from any one source.
2. Irregularities of demand in areas of large construction projects.
3. Variable behavior patterns over time for different economic sectors.
4. The poor relationship between the demand for rock materials from public agencies and economic indicators.
5. The erratic demand for stone as a result of higher costs relative to sand and gravel.
6. The partial interdependence of population and employment, two of the econometric explanatory variables.

The major conclusion of the study to date is that the demand for rock material is much larger than was commonly thought. This very interesting project is on schedule and the published report should be available from the Department after July 1979. The report should help fill a very real need. □

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ABSTRACTS

GEOLOGY AND MINERAL DEPOSITS OF THE BOHEMIA MINING DISTRICT, LANE COUNTY, OREGON, by Michael Paul Schaubs (M.S. in Geology, Oregon State University, 1978)

The Bohemia District is located in the Western Cascade Range, Lane County, Oregon. Over one million dollars worth of metals have been produced from mines of this area since 1872, making it one of the most important districts of the Cascades.

Bedrock consists of a portion of the Oligocene-Miocene Little Butte Volcanic Series and is composed principally of a thick section of pyroclastic tuffs overlain by massive interstratified flows of andesite and basalt. Other volcanic lithologies include flows of dacite porphyry and a multi-lithic breccia. Folds of small amplitudes and low angle unconformities of local distribution are widespread throughout the volcanic sequence and are interpreted to have formed by gentle deformation related to shallow subvolcanic magmatism.

Felsic plutons of probable Miocene age intrude the volcanic pile, and there are over 40 small plugs in addition to the Champion Stock. The plugs are predominantly quartz diorites, whereas the composite Champion Stock contains granodiorite, quartz monzonite, and felsic aplite.

Vein-type mineralization is widespread in both the volcanic and plutonic rocks of the district. Although gold has been the most important metal, the deposits are dominated by zinc, lead and copper that occur in veins containing chiefly quartz, carbonates, sphalerite, galena, chalcopyrite and pyrite. The veins have two principal orientations; the dominant vein set trends N. 65° W. and the secondary cross-veins trend N. 20°E.

Contemporaneous with vein mineralization was the formation of at least eight breccia pipes. These bodies are roughly cylindrical in shape, vertically oriented, and vary from 3 m to over 100 m in diameter. The constituent clasts are derived from the nearby country rocks and range from 1 mm to 0.5 m in diameter. The breccia fragments and surrounding country rock have been intensely altered to a quartz-sericite ± tourmaline assemblage. An admixture of quartz and tourmaline cements the breccias. Because the pipes grade upward into shatter breccias of highly fractured rock with little displacement, they are interpreted to have originated by collapse.

Low temperature propylitic alteration is widespread throughout the district and affects both volcanic and plutonic lithologies. Smaller zones of higher rank quartz-sericite and potassic alteration are localized in areas of structural weakness, such as breccias, and shear and fracture zones.

Geochemical abundances of trace elements in rock samples indicate that the district is zoned with respect to base metals. Anomalously high concentrations of copper, zinc, and lead are progressively encountered from east to west across the district. The molybdenum anomaly is coincident with that of copper, and these are roughly centered upon the zone of potassic alteration.

Hydrothermal alteration and mineralization of the district are related to the pluton. Evidence for such a genetic relationship includes the close association of all Cascades mineral districts with felsic intrusions, structural features related to these intrusions, and chemical and mineral zonations within the district. Geologic and geochemical evidence that includes alteration patterns, fluid inclusions, breccia pipes, and mineral and trace element zonations, collectively suggest that only the highest levels of the hydrothermal system are exposed, and that it is possible that porphyry-type mineralization is present at depth.

THE PETROLOGY AND STRATIGRAPHY OF THE PORTLAND HILLS SILT, by Rodney Thomas Lentz (M.S. in Geology, Portland State University, 1977)

The present investigation carefully examines the lithology and stratigraphy of the Portland Hills Silt on the basis of field observations and detailed lateral and vertical sampling. Over 100 uniform and variable depth samples were obtained from outcrops and 4.7-13.4 m (15-45 ft) deep sections located in and around the Tualatin Mountain region, Oregon and Washington.

The Portland Hills Silt is uniform both in texture and composition. The average grain size distribution indicates 77 percent silt-, 19 percent clay- and 5 percent sand-sized particles, very poor sorting and a fine skewed grain size distribution. The median grain size fines westward from about .041 mm near the Portland basin, to .022 mm to the west slope of the Tualatin Mountains.

Quartz and feldspar constitute 35 to 36 percent respectively of the total mineral composition. Clay minerals (15%), coarse-grained micas (6%), rock detritus and volcanic glass (5%), and heavy minerals (3%) make up lesser quantities. The heavy mineral suite is composed of hornblende (41%), opaques (17%), epidote (15%), augite (10%), a variety of metamorphic species and very minor hypersthene.

The Portland Hills Silt is overlain by the Willamette Silt and underlain or possibly interstratified with the Boring Lava. Carbon-14 age dating and paleomagnetic data suggest deposition between approximately 34,000 and 700,000 (?) years B.P. The silt's thickness decreases from about 37 m (120 ft) on the east side of the Tualatin Mountains to near zero in the Chehalem Mountains, some 27 km (18 mi) to the west.

The deposit is basically massive. However, deeper exposures may reveal up to four 2-8.5 m thick silt units, which are delineated by darker paleosols. The units are tentatively correlated with major glacial deposits of western Washington; the Orting and Stuck Drifts and the Upper and Lower Tills of the Salmon Springs Drift. The silt is also correlated, in part, with the Palouse Soil of eastern Washington.

The distributional, textural and morphological character of the Portland Hills Silt strongly indicates a loessial origin from the sediments of the Columbia River flood plain. □

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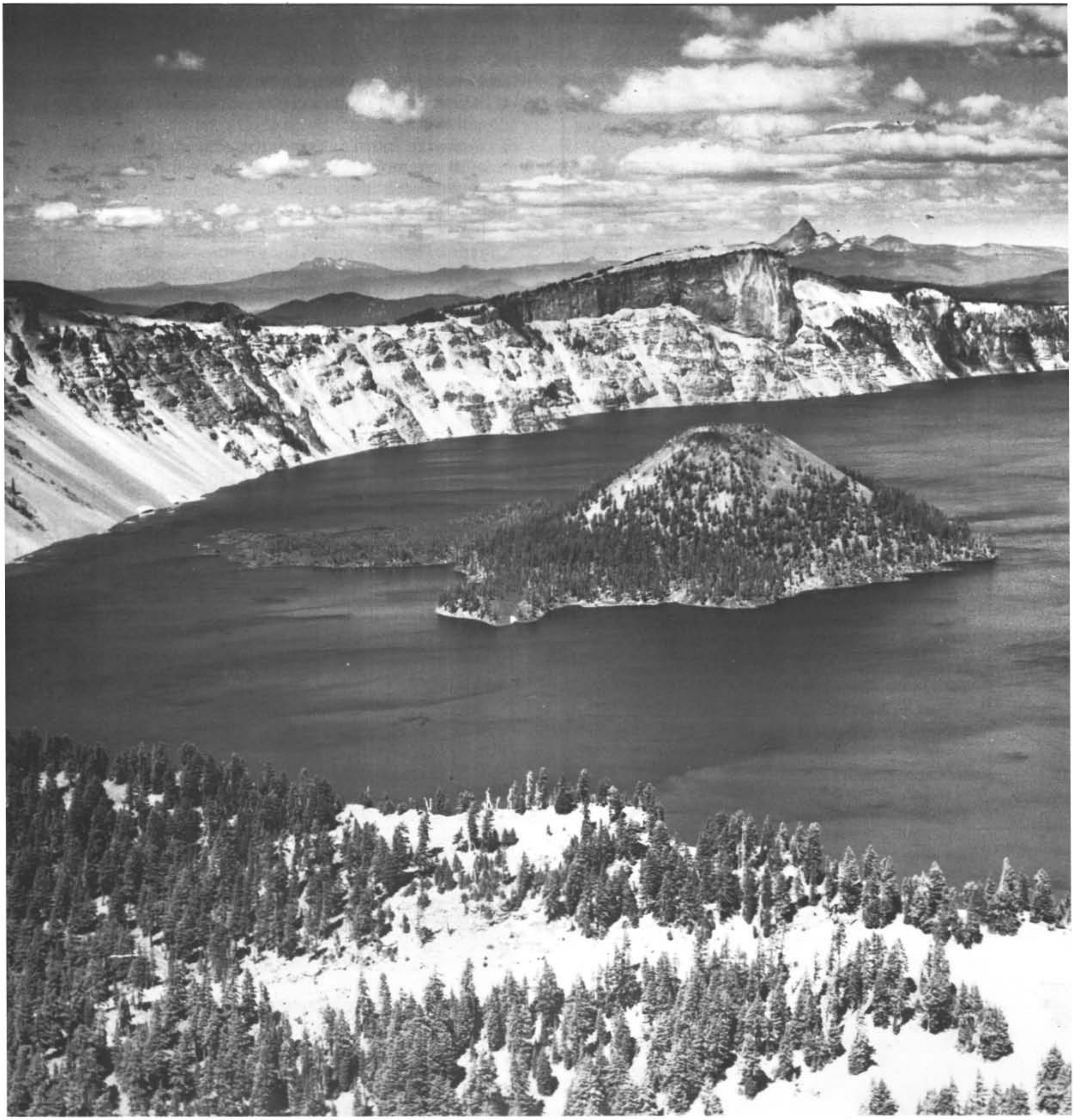

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Cover Photo

Crater Lake, one of the areas in Oregon being studied by the U.S. Geological Survey as part of its geothermal research program. The article beginning on page 103 lists USGS activities throughout the Cascade Range. (Oregon State Highway Division photo)

Old mines are dangerous

The tragic death in April of a miner near Quartzville should serve as a warning to all who work in—or visit—old mines in Oregon. Each year, the Oregon Department of Geology and Mineral Industries prints warnings about the dangers of mines in the hope that this type of accident may be prevented. We also have a free brochure that describes in detail some of the unexpected dangers that exist in abandoned mines, caves, and open pits.

Common dangers in old mines include:

1. Rotten timber (posts and timbers supporting roofs and walls).
2. Broken or rotten ladders, steps, stairways, or any other means for getting in and out.
3. Unsupported roofs and walls (danger of falling rocks).
4. Bad air (lack of oxygen or the presence of deadly gases).
5. Underground holes and shafts (covered or uncovered).
6. Water (unfit for drinking or the danger of drowning).
7. Underground fires (burning up oxygen or giving off poisonous gases).
8. Abandoned explosives (dynamite, powder, and detonators).
9. Snakes, spiders, scorpions, and poisonous insects.
10. Danger of becoming lost.
11. Caving ground (ledges, rims, and mine surfaces). □

CONTENTS

U.S. Geological Survey geothermal research program in the Cascade Range

INTRODUCTION

This list summarizes U.S. Geological Survey (USGS) activities that are already in progress or are about to begin in the Cascade Range of Oregon, Washington, and California. The list is divided into two parts: (1) projects associated with the geothermal research program, and (2) activities outside the geothermal research program. Work in progress by non-USGS groups under contracts, extramural grants, or Department of Energy funding is not included.

The Cascade Range comprises one of the major belts of active volcanoes of the world. Being located near several population centers, the Cascade volcanic chain would seem to be an attractive prospect for the development of geothermal energy. However, the geothermal potential of the Cascades cannot be accurately assessed until the geological history of the region, its structure, hydrology, and volcanic and hydrothermal processes are more thoroughly understood.

In combination with other research groups, the U.S. Geological Survey Geothermal Research Program has undertaken a number of long-term geologic, geophysical, geochemical, and hydrologic studies of the Cascade Range on both regional and local bases. A geologic map of the Cascade Range will be compiled and supplemented with detailed mapping in specific areas. Aeromagnetic, gravity, and heat flow maps are being prepared to complement the geologic maps. Additional geophysical investigations include both active and passive seismic, electrical, and remote sensing techniques. Petrologic and geochronological data are being acquired in conjunction with geologic mapping. Studies of the geochemistry of hydrothermal alteration and geothermal fluids have also been initiated. Reports and maps will be published by the USGS and in scientific journals as individual projects are completed.

A significant portion of the work included in the USGS program is being done by universities, state agencies, and private institutions under contracts and extramural grants. Throughout these investigations, a conscientious effort is being made to coordinate activities with others working in the Cascade Range under funding from different sources (for example, the Department of Energy). The Geothermal Research Program Coordinator has designated Charles R. Bacon, Menlo Park, California, as geologist responsible for coordination of USGS geothermal investigations in the Cascades.

Letters after researchers' names indicate USGS offices in the following cities: D = Denver, Colorado; MP = Menlo Park, California; R = Reston, Virginia; S = Seattle (LIA), Washington; and SLC = Salt Lake City, Utah.

USGS PROJECTS IN THE CASCADE RANGE ASSOCIATED WITH THE GEOTHERMAL RESEARCH PROGRAM

Geophysical studies

Geothermal geophysics—D. R. Mabey (SLC): Evaluation of KGRA's in Cascades using geophysical data including aeromagnetic, gravity, SP, MT, AMT, EM, and active seismic techniques.

Teleseismic and microearthquake geothermal studies—H. M. Iyer (MP): Delineation of magma systems and the deep structure under the Cascades, particularly in Oregon, through microearthquake surveys and teleseismic P-wave studies.

Geothermal/Tectonic seismic studies—C. S. Weaver (MP): Detailed seismicity studies to understand the tectonic environment of the Cascades in relation to possible geothermal systems, particularly in central and southern Washington.

Active seismic exploration of geothermal sources—D. P. Hill (MP): Detailed determination of the velocity structure of the crust and upper mantle beneath the Cascades. Use of this information in interpreting the pressure-temperature conditions in the crust in conjunction with laboratory measures of physical properties.

Geothermal processes, heat flow—A. H. Lachenbruch (MP): Measurement and theoretical studies of heat flow in the Cascades of northern California and southern Oregon.

Geoelectric studies—W. D. Stanley (D): Use of deep electrical sounding techniques to investigate crustal structure beneath the Cascades.

Geophysical characterization of young silicic volcanic fields—D. W. Williams (D): Characterization of volcanic geothermal areas using gravity, aeromagnetic, and other geophysical data.

Engineering geophysics—H. D. Ackermann (D): Determination of the relationships between the rock properties in areas of geothermal interest and their seismic-wave transmission properties from seismic measurements in the field.

Geothermal regional studies—R. Simpson (D): The use of deep-sounding magnetotelluric measurements to provide information on broad crustal-mantle structure and on areas of geothermal interest.

Electrical techniques applied to shallow- to medium-depth exploration for geothermal resources—D. B. Hoover (D): Development and application of AMT, SP, and telluric techniques for exploration and characterization of geothermal systems to a depth of about 1 km.

Transient geomagnetic and telluric investigations—J. N. Towle (D): Use of a geomagnetic-telluric array to study the conductivity of the crust and upper mantle under the Cascades.

Heat flow, Crater Lake—D. L. Williams (D): Measurement of heat flow in bottom sediments and photographic coverage of selected sites on the bottom of Crater Lake, Oregon.

Seismic stratigraphy and geologic history of the floor of Crater Lake—C. H. Nelson (MP): Detailed seismic reflection profiling of the floor of Crater Lake to study sedimentation processes and relations between submerged volcanic features.

Lineament analysis—D. Knepper (D): Preparation of maps of lineaments in the Cascade Range from LANDSAT imagery.

Geologic studies

Geology of Newberry and Three Sisters Volcanoes—N. S. MacLeod (MP): Geologic mapping and related studies of Newberry and Three Sisters volcanoes. Geologic map of the west half of the Crescent 2° Quadrangle, Oregon.

Hydrothermal alteration in the Cascades—M. H. Beeson (MP): Detailed field mapping and laboratory petrological and mineralogical studies of selected areas of hydrothermal alteration associated with active and fossil geothermal systems of Western and High Cascades.

Geology of young volcanic rocks and thermal areas in and around Lassen Volcanic National Park—L. J. P. Muffler (MP): A geologic study of the volcanic rocks and hydrothermally altered areas in the region of Lassen Peak to provide the geologic framework for understanding the geothermal resources of the southernmost Cascades.

Regional volcanology—R. L. Smith (R): Classification, characterization, and geothermal evaluation of volcanic systems in the Cascades.

Volcanology and petrology of Mt. Shasta—R. L. Christiansen (MP): A study of the volcanic evolution of Mt. Shasta and the Cascade Range in its vicinity.

Medicine Lake Volcano—J. M. Donnelly (MP): Geology of Medicine Lake Highland with emphasis on its volcanic evolution in time, space, and composition.

Volcanic evolution of the Crater Lake region—C. R. Bacon (MP): Geology and petrology of Mt. Mazama and vicinity, with emphasis on processes leading to the development of shallow silicic magma reservoirs.

Mt. St. Helens—W. Hildreth (MP): Geochemistry and petrology of Mt. St. Helens, in collaboration with the USGS volcano hazards studies and other non-Survey researchers.

Regional petrologic reconnaissance of the Cascades—W. Hildreth (MP): Geochemical and isotopic reconnaissance of the many lesser vents between the major stratocones to develop a better understanding of the characteristic scales and longevities of the Cascade volcanic foci.

Geologic map of the Cascades—R. G. Luedke (R): Compilation of a geologic map of the Cascade Range in California, Oregon, and Washington to be used in conjunction with regional geophysical maps for evaluation of the geothermal resource potential and tectonic regime of the modern Cascade Range.

Fluid geochemistry and hydrology

Rock-water interactions—R. O. Fournier (MP): Development of geochemical techniques for estimating conditions deep in hydrothermal systems from chemistry of geothermal fluids.

Geochemical indicators—A. H. Truesdell (MP): Application of chemical and isotopic methods to the study of geothermal systems to determine subsurface temperatures, flow directions, origins, and ages of geothermal waters.

Chemistry of thermal waters—R. H. Mariner (MP): Collection and analysis of liquid and gas samples from thermal springs and wells of the Western and High Cascades for chemical and isotopic data used to estimate reservoir temperatures, outline areas for further geothermal exploration, identify potential pollution problems, and estimate recharge-discharge relations.

Geothermal hydrologic reconnaissance of the southern Cascades—E. A. Sammel (MP): Description and evaluation of the hydrology of several geothermal areas in the southern Cascades, including the Klamath Falls, Newberry, Medicine Lake, Shasta, and Lassen areas.

Hydrologic studies at Mt. Hood—J. H. Robison (MP): Hydrologic reconnaissance of Mt. Hood with emphasis on the warm springs and drill holes on the

North and Middle Sister, part of the Three Sisters Wilderness Area now being studied by the USGS as part of its geothermal research program. (Oregon State Highway Division photo)

south flank.

Geochronology

Potassium-argon dating—M. A. Lanphere (MP): Determination of age and evolution rate of volcanic centers in the Cascades using K-Ar radiometric dating.

Thermoluminescence dating—R. J. May (MP): Development of the thermoluminescence (TL) dating technique for volcanic rocks in the age range of 10^3 to 10^5 years.

Carbon-14 dating—S. W. Robinson (MP): Use of radiocarbon dating to provide chronology of episodes of late Pleistocene volcanism and lacustrine episodes in areas of geothermal potential.

Paleomagnetic studies—C. S. Grommé (MP): Dating young volcanic rocks using the paleomagnetic record of Holocene secular variation and the application of other paleomagnetic and rock-magnetic techniques to the study of volcanic geothermal systems.

USGS ACTIVITIES OUTSIDE THE GEOTHERMAL RESEARCH PROGRAM

Geophysical studies

Pacific states geophysical studies—A. Griscom (MP): Synthesis and interpretation of gravity and aeromagnetic data over northern California to gain a better understanding of the regional tectonism and structure.

California gravity—H. W. Oliver (MP): Preparation of interpretive text to go with preliminary Bouguer gravity map of California (1:750,000).

Geomagnetic polarity time-scale and paleosecular variation—E. A. Mankinen (MP): Paleomagnetic data from volcanic areas in California, Nevada, Arizona, and New Mexico will be used to determine paleosecular variation in the western United States during the last five to six million years.

Geophysical studies in Medford 2° Quadrangle (CUSMAP)—R. J. Blakely (MP): Gravity and aeromagnetic studies in the Medford 2° Quadrangle.

Thermal infrared studies of Cascade volcanoes—J. D. Friedman (D): Repetitive thermal infrared surveys of Cascade volcanoes for the purpose of delineating and monitoring areas of anomalously high surface temperature.

Remote sensing geothermal—K. Watson (D): Preparations of master image set for Mt. Hood and Newberry Crater areas from repetitive thermal infrared and multispectral data and ground meteorological measurements.

Geologic studies

Volcanic hazards overview—D. R. Mullineaux (D): Preparation of overview maps of volcanic hazards for Oregon (1:1,000,000) and western U.S. (1:2,500,000).

Volcanic hazards—D. R. Crandell (D): Rocks and unconsolidated deposits of volcanic origin and of late Quaternary age are being studied at volcanoes in

Newberry Volcano, near Bend, Oregon. Note Big Obsidian Flow in center of photo. The USGS is studying Newberry Volcano and surrounding volcanic features with its geothermal research program. (Oregon State Highway Division photo)

Washington, Oregon, and California for the purpose of evaluating potential hazards from future eruptions. Includes recent eruptive histories of Glacier Peak (J. E. Beget, Univ. Washington), Mt. St. Helens (R. P. Hoblitt [D]), Mt. Hood (Crandell), Mt. Shasta (C. D. Miller [D]), and studies of Holocene pyroclastic flows (Crandell).

Tephra hazards, Cascade Range volcanoes—D. R. Mullineaux (D): Study of large single shower beds of tephra, mainly from Mt. St. Helens and Mt. Mazama, to evaluate potential tephra hazards downwind from Cascade Range volcanoes.

Tephrochronology of the western region—A. M. Sarna-Wojcicki (MP): Isotopic age determination, and correlation of late Cenozoic ashes and tuffs by means of instrumental neutron activation, X-ray fluorescence, and electron probe analyses of volcanic glass, and by petrography and paleomagnetism. Includes studies of tephra units and source areas in the south, central, and north Cascade Ranges.

Sacramento Valley—Northern Sierran Foothills—E. J. Helley (MP): Preparation of geologic maps of Quaternary alluvial deposits and late Cenozoic volcanic rocks of the Sacramento Valley and Northern Sierran Foothills, with special emphasis on the age of associated faulting.

Medford-Coos Bay Quadrangles (CUSMAP)—J. G. Smith (MP): Preparation of a multidisciplinary land-resource analysis folio of Medford 2° Quadrangle, with primary emphasis on the evaluation of potential mineral resources and their relation to regional structure, tectonostratigraphic units, and plate tectonic models.

Geochemical exploration of Medford 2° Quadrangle (CUSMAP)—D. J. Grimes (D): Collection and analysis of stream sediment samples for 32 elements; preparation of preliminary maps and identification of target areas for detailed studies.

Mineral resources of Spirit Lake Quadrangle—R. P. Ashley (MP): Preparation of a geologic map and reports on geology and mineral resources of Spirit Lake 15' Quadrangle, Washington.

Wenatchee 2° Quadrangle—R. W. Tabor (MP): Preparation of geologic maps of four 1:100,000 quads making up Wenatchee 2° Quadrangle, Washington, with emphasis on tectonics.

Port Townsend 1:100,000 Quadrangle, Washington—J. T. Whetten (S) and H. D. Gower (MP): Preparation of geologic map with emphasis on tectonics.

Geologic map of Columbia Plateau; Columbia River Basalt—D. A. Swanson (MP); **Genesis of basalt**—T. L. Wright (R): Continuing studies of Columbia River Basalt in southeastern Washington and northeastern Oregon.

Seismo-tectonic analysis of Puget Sound province—H. D. Gower (MP): Investigation of suspected Quaternary and bedrock faults by marine seismic profiling; aeromagnetic, gravity, and geologic investigation; geologic reconnaissance of arcuate topographic feature east of Seattle in Western Cascade Range.

Tectonic analysis—K. F. Fox, Jr. (MP): Compilation of tectonic map of Washington (1:500,000).

Mt. Baker monitoring—D. Frank (S): Photographic surveys of fumarolic emission and associated snowmelt patterns, and chemical analysis of stream draining Sherman Crater for the purpose of monitoring activity of Mt. Baker.

Wilderness studies

Caribou-Thousand Lakes—A. Till (University of Washington)

Baker Cypress-Lava Rock—J. A. Peterson (MP)

Sky Lakes—J. G. Smith (MP)

Salmo Priest—F. K. Miller (MP)

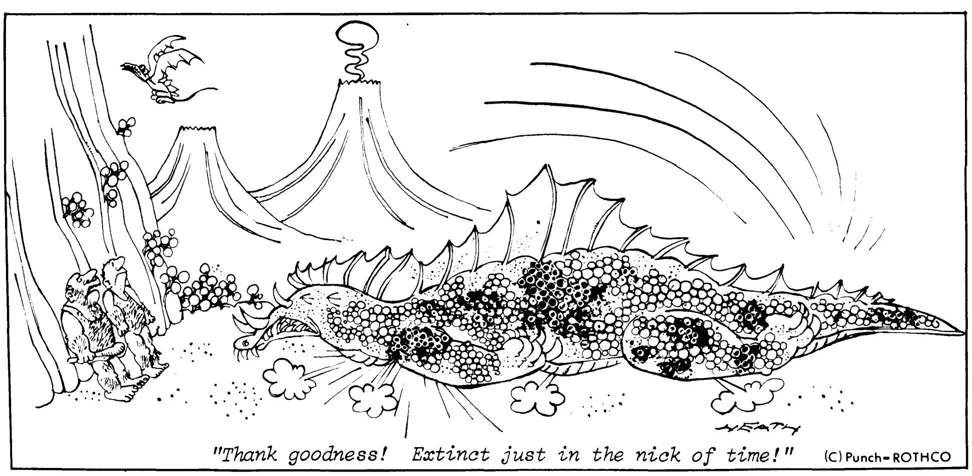
Three Sisters—N. S. MacLeod and G. W. Walker (MP)

Mt. Washington—N. S. MacLeod (MP)

Mt. Hood-Zigzag—T. E. C. Keith (MP)

Goat Rocks—D. A. Swanson (MP)

Glacier Peak—J. G. Evans and R. W. Tabor (MP) □



"Thank goodness! Extinct just in the nick of time!" (C) Punch-ROTHCO

An exposure of limestone at Gray Butte, Jefferson County, Oregon

by Melvin Ashwill, retired public school teacher, Route 1, Box 393, Madras, Oregon 97741

Geology is a field-oriented science and, as such, is founded on observations by many persons. No agency has staff to study personally all the geology the field has to offer, and new discoveries are continually being made. In this article, Melvin Ashwill reports on a recent discovery in the Gray Butte area that may be of considerable interest to many of our readers.

Gray Butte is a 5,108-ft promontory in southern Jefferson County, Oregon (Figure 1). The area, mapped as Oligocene-Miocene John Day Formation (Waters, 1968), has been considered to be made up of continental deposits.

On the lower west flank of the butte, I recently located a small exposure of light-gray, unfossiliferous, recrystallized limestone in association with some arenites. This exposure appears to be a window into a formation that is older than the surrounding rocks.

Previous studies of the area include those by Russell (1905), Stearns (1931), Hodge (1942), Williams (1957), Wells and Peck (1961), Waters (1968), and Stensland (1970).

Several of these investigators noted that the basalt immediately to the southwest of the study area appeared to be among the oldest rocks nearby, and some estimated an Eocene age for them. Likewise, some

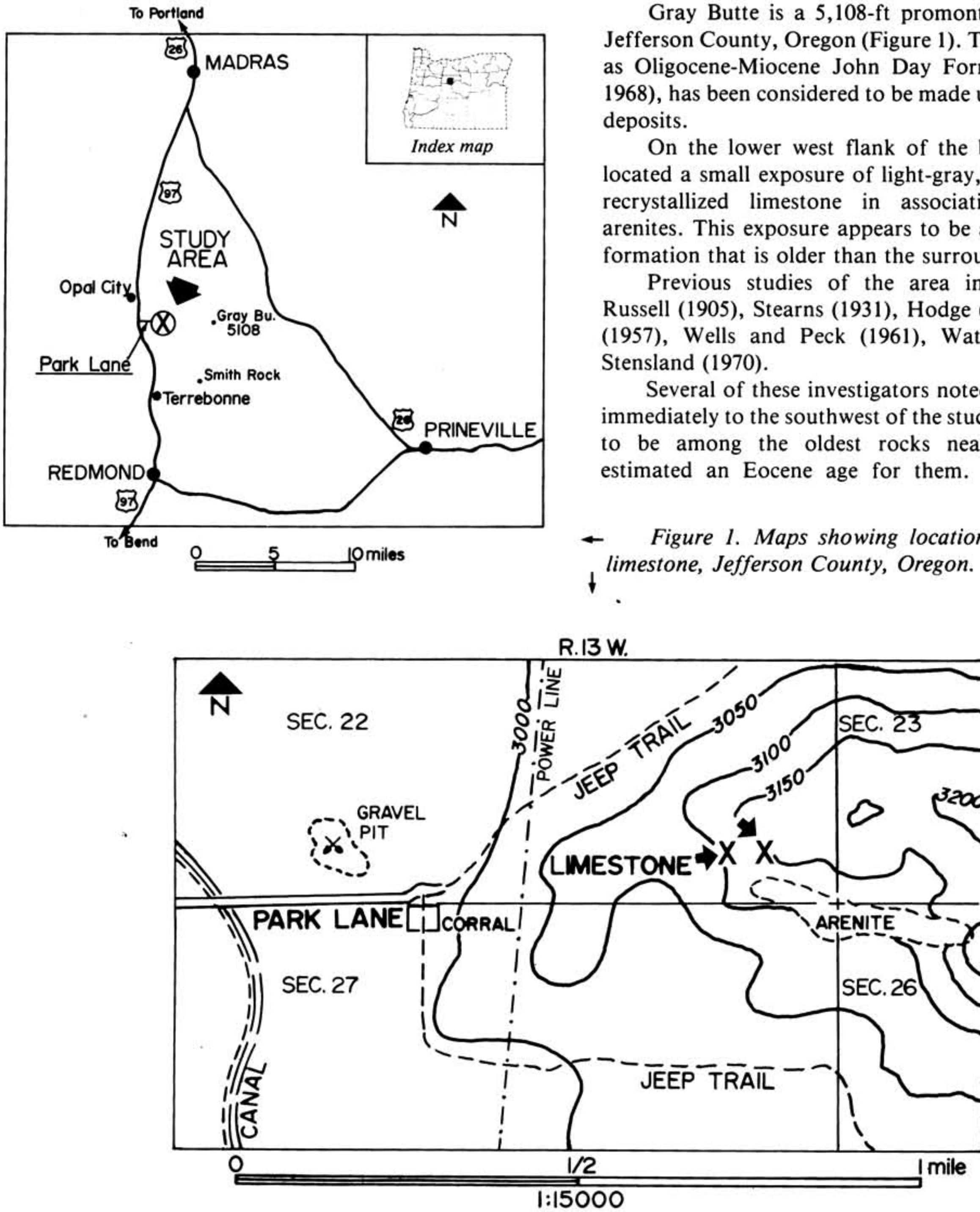


Figure 1. Maps showing location of Gray Butte limestone, Jefferson County, Oregon.

Figure 2. Limestone cropping out at Gray Butte. Beds are dipping steeply.

workers suggested the presence of an anticline whose northeast trending axis extends roughly through the study area.

The scant exposures of limestone (Figures 2 and 3) occur in strata ranging from 4 to 14 in. in thickness. By scraping away the thin topsoil, an observer can follow the limestone for about 150 ft. The sequence is more than 45 ft thick and includes tuffaceous layers varying from less than 2 ft to more than 6 ft in thickness. The strata strike east-northeast and dip 75° to the north-northwest. Other dips recorded by Williams (1957) within 5 mi of the study area are between 10° and 30°.

Arenites and other clastic rocks crop out about 150 ft south-southeast of the limestone. They strike north-northwest, extend for several hundred yards, and also dip steeply. The clastic sediments vary laterally from sand-sized grains to cobble-sized quartz conglomerate. Although the clastic rocks are lower on the slope than the limestone, their true stratigraphic relationship remains obscure. The arenite sequence is over 50 ft thick and is overlain by more than 20 ft of mudstone containing as yet unidentified fossil wood.

The lithological differences in these rocks from others at Gray Butte, their anamalously steep dips, the indications of metamorphism in the recrystallization of the limestone, and the quartzic arenites all suggest an older age for these rocks than was previously believed. They appear to lie in the axis of an anticline (Figure 4).

Three miles to the south, the tuffs at Smith Rock contain inclusions of limestone country rock (Bruce Nolf, personal communication, 1978), lie stratigraphically above the rocks of the study area, and are John Day (mid-Tertiary) in age. A mile east of the limestone and stratigraphically between it and the Smith Rock tuff, a relatively unstudied assemblage of fossil plants suggests that the rocks there may be older than John Day age.

Further study will be necessary to determine if the fossils are intermediate in age between the limestone and the Smith Rock tuff. Should subsequent study prove that such is the case, an unusual geologic column indeed is exposed at the surface in this area: the Piocene deposits just west of Prineville, the Miocene Columbia River Basalt Group east of Lone Pine Flats, the John Day Formation at Smith Rock and the north wall of Sherwood Canyon, and the successively older rocks of the study site.

Directions for finding the limestone exposure, which lies in the SE¼SE¼ sec. 22, T. 13 S., R. 13 E., are as follows: 15 mi south of Madras, Oregon, on U.S. Highway 97, turn east on Park Lane. While driving the 2 mi east to the end of Park Lane (Figure 5), notice the small power line along the road. In the distance ahead, the line continues straight ahead along a section line past the end of Park Lane. This power line is important to orientation and is not to be confused with the two larger high-voltage lines on steel towers crossing the area in a different direction.

Two miles beyond the highway, Park Lane ends with a private road that turns 90° to the right and a National Grasslands road continuing in a northeasterly direction. At this junction stands a wooden corral, with a gate at each end, allowing access to a jeep trail. Be sure to close the gates behind you, both as you enter and as you leave. After going through the corral, follow the jeep trail three-quarters of a mile, park your vehicle, and walk due north a quarter of a mile. At this point, you will reach the small power line described above, and within 4 ft of the base of one of the poles (#229001), you will find a section corner marker in plain view.

The limestone described in this article lies approximately 730 ft west and 320 ft north of this point. A second small exposure of limestone lies about 100 yds west of the first.

Figure 3. Linear blocks of limestone along ledge at Gray Butte. Between exposed blocks, ledge is covered by thin topsoil.

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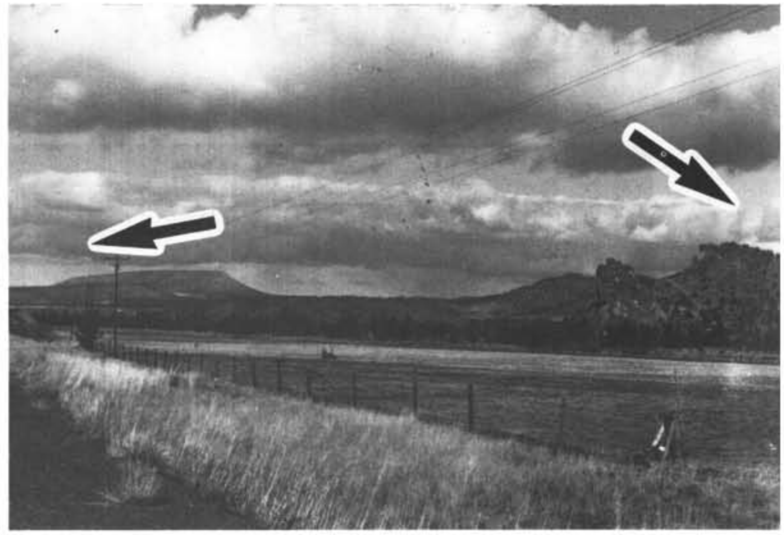
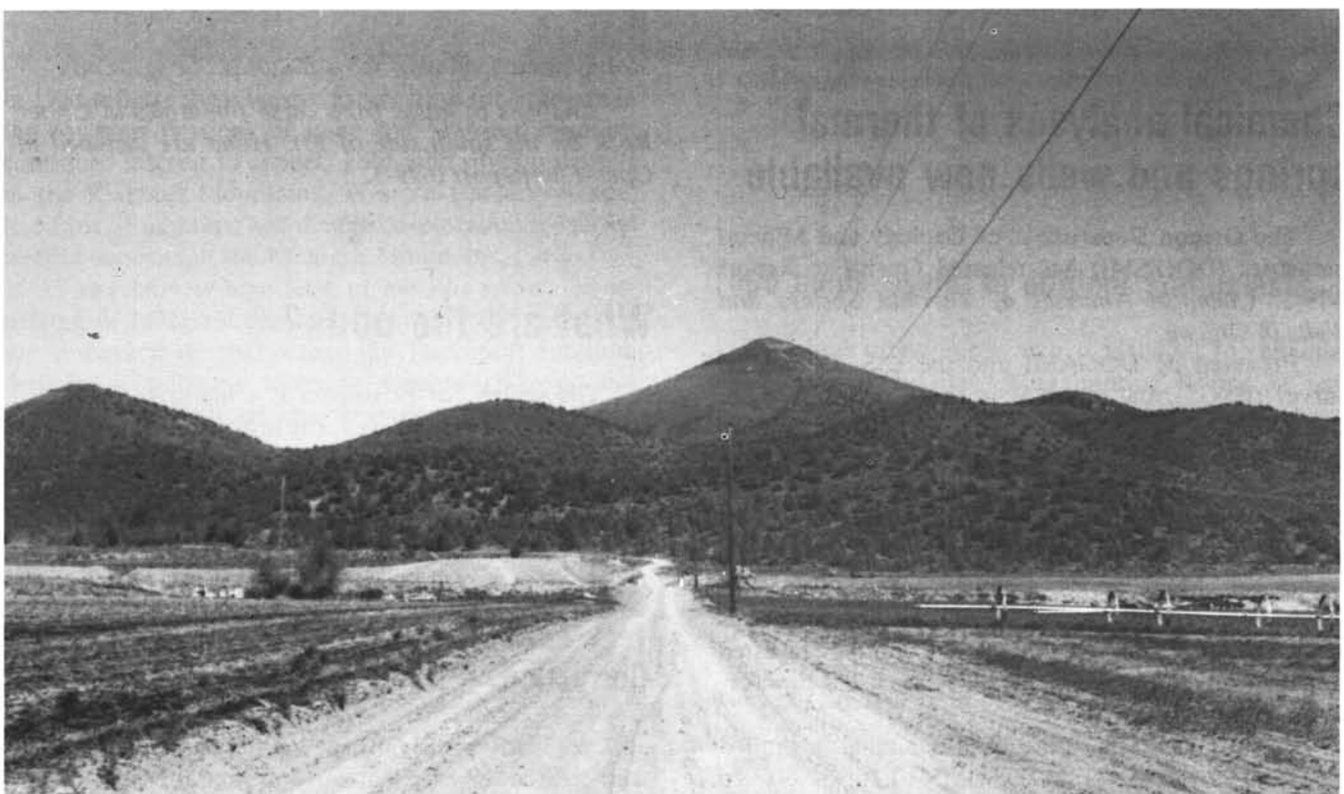


Figure 4. Looking northeast toward study area from near Terrebonne. Arrows indicate dips of anticline.

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st Meridian: U.S. Geological Survey Miscellaneous Geological Investigations Map I-325, in cooperation with the Oregon Department of Geology and Mineral Industries.

Williams, H., 1957, A geologic map of the Bend Quadrangle, and a reconnaissance geologic map of the central portion of the High Cascade Mountains: Oregon Department of Geology and Mineral Industries. □

Figure 5. Looking east along Park Lane. Highest peak is summit of Gray Butte. Limestone is reached by following jeep trail through corral. Power line that parallels road and continues straight east is important in locating small limestone exposures.



Analyses of gases from these fumaroles at Crater Rock on the south side of Mt. Hood are included in Open-File Report 0-79-3.

Chemical analyses of thermal springs and wells now available

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released Open-File Report 0-79-3, *Chemical Analyses of Thermal Springs and Wells in Oregon.*

Prepared by DOGAMI and the U.S. Geological Survey (USGS), the report is in the USGS data base, GEOTHERM, in Reston, Virginia. The information includes chemical analyses of waters, condensates, and gases from thermal springs, wells, and fumaroles in Oregon.

Most of the thermal springs shown in DOGAMI's Geological Map Series GMS-10 Map, *Low- to Intermediate-Temperature Thermal Springs and Wells in Oregon,* are analyzed in 0-79-3. Counties are listed alphabetically, and specific localities are listed similarly within the counties.

0-79-3 and GMS-10 are both available in limited supply. 0-79-3 sells for $3.00, GMS-10 for $2.50. To order, write to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201. Payment must accompany orders of less than $20.00. □

What are the odds?

The search for petroleum is a high-risk business. For a new field wildcat well, the historic odds are better than nine to one that the well will prove to be a dry hole, and about fifty to one against finding oil or gas in commercially significant quantities.

Correction

We inadvertently misspelled the name of the artist who created the excellent cartoon that appeared in last month's OREGON GEOLOGY (v. 41, no. 6, p. 90). We apologize to Art Bimrose of the *Sunday Oregonian*— and thank him again for permission to reprint his most appropriate cartoon.

Mineral exploration activity increases

Oregon is experiencing a steady increase in exploration for minerals and mineral fuels as the nation increasingly turns toward domestic sources of metals and fossil fuels and as geologic studies outline new areas of potential resource occurrence.

A survey of expenditures made by private companies in searching for metals, petroleum and natural gas, and geothermal energy provides a direct measure of this prospecting activity. The following table shows a dramatic increase in each category in calendar year 1978, as compared to 1977.

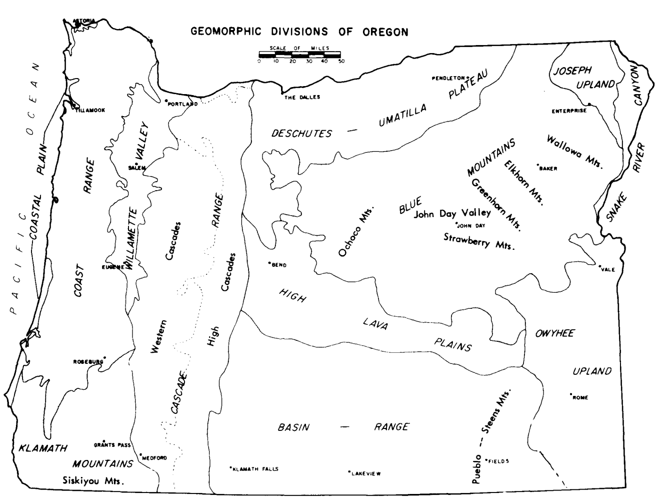
EXPLORATION EXPENDITURES

	Metals (incl. uranium)	Oil and gas	Geothermal (private)
1978	$4,435,402	$4,608,000	$1,298,000
1977	3,600,000	2,000,000	600,000
1976	2,300,000	2,000,000	1,400,000

METALS

The surge in exploration for metallic commodities in 1978 reflects the intensive exploration for uranium in the southern portions of Lake and Malheur counties; continued interest in copper, gold, and silver prospects in the Klamath Mountains, Western Cascade Range, and Blue Mountains; and detailed exploration for nickel laterite deposits in the Klamath Mountains.

The relatively high level of metallic mineral prospecting in 1978 will continue through 1979, reflecting the discovery of the potentially important uranium deposit in southern Malheur County (Brooks and others, 1979). All of the Basin-Range, High Lava Plains, and Owyhee Upland provinces are currently being re-evaluated for uranium.



OIL AND GAS

The search for natural gas and petroleum accelerated in 1978 as drilling by Mobil Oil Corporation, John Rex, and Reichhold Energy Corporation tested a variety of geologic environments in western Oregon. The increase in activity will continue in 1979 due to the announcement of the discovery of natural gas in Columbia County by Reichhold and its partners, Northwest Natural Gas Company and Diamond Shamrock Corporation.

GEOTHERMAL ENERGY

Drilling and related exploration activities by private industry increased in 1978 compared to the previous years, but the only deep test was drilled by Northwest Natural Gas to a depth of 4,003 ft at a site west of Mt. Hood in Clackamas County, under a contract with the U.S. Department of Energy. In 1979, the level of spending for geothermal exploration will likely be approximately the same as in 1978.

REFERENCE

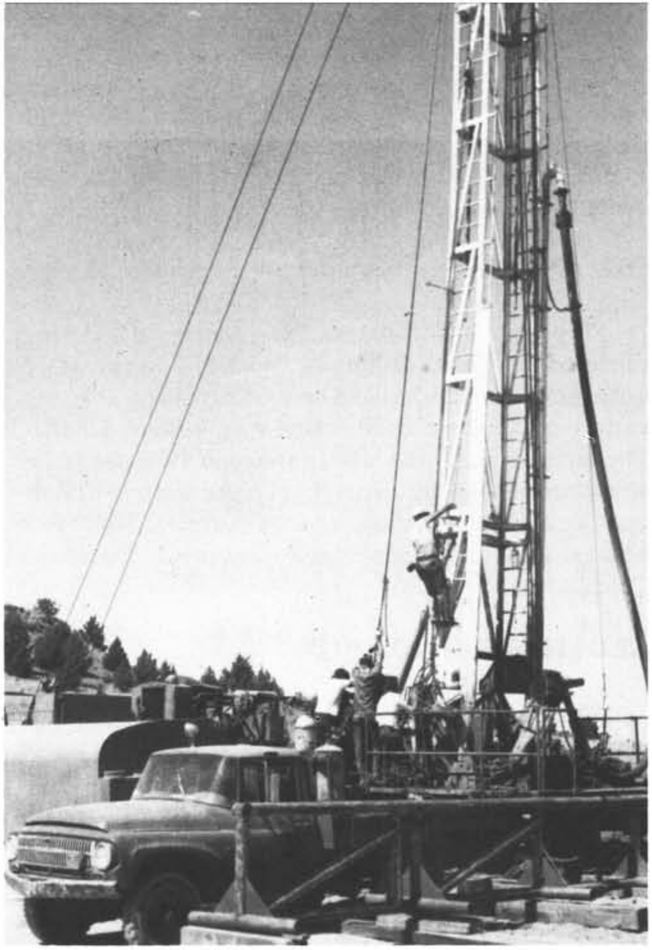
Brooks, H. C., Gray, J. J., Ramp, L., and Peterson, N.V., 1978, Oregon's mineral industry in 1978: Oregon Geology, v. 41, no. 4, p. 55-62. □

Topo maps useful to outdoor enthusiasts

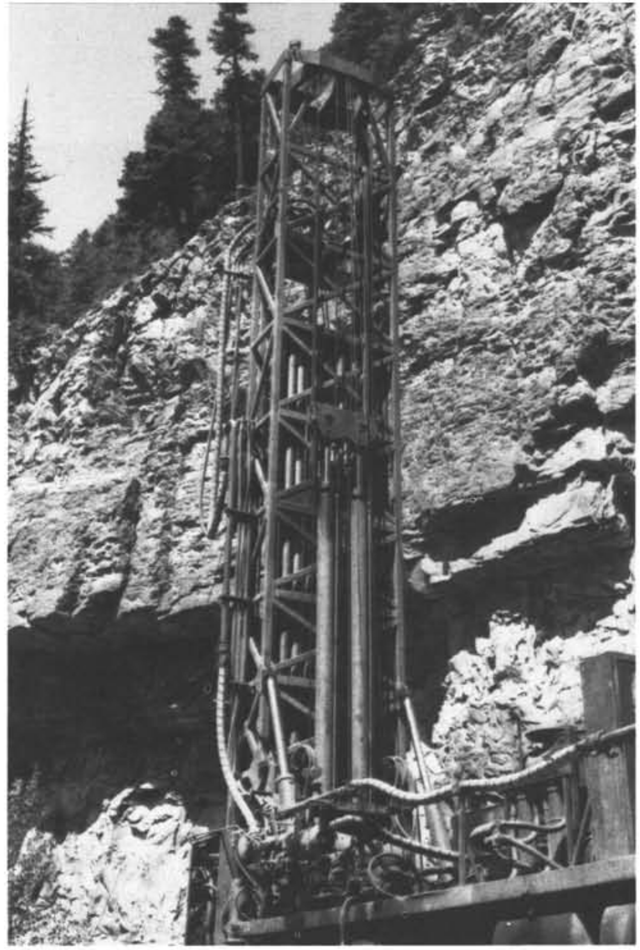
A good topographic map is essential for anyone who plans to spend time hiking, hunting, fishing, or just plain walking outdoors.

Some of the best topographic maps available are made by the U.S. Geological Survey (USGS). The USGS has designed over 40,000 different maps, originally for use by such professionals as geologists, engineers, and planners. The maps are also available to the public. The USGS sells maps by mail at $1.25 each for the most popular sizes. The Portland office of the Oregon Department of Geology and Mineral Industries also has USGS Oregon 7½- and 15-minute quadrangle maps available for over-the-counter sale at $1.50 each.

Indexes of available maps can be obtained without charge from the USGS. For areas east of the Mississippi River, write Branch of Distribution, USGS, 1200 So. Eads St., Arlington, Virginia 22202. For areas west of the Mississippi, write Branch of Distribution, USGS, Box 25286 Federal Center, Denver, Colorado 80225.



Drilling began June 5, 1979, on Agoil's "Hay Creek Ranch No. 2." The wildcat is located 8 mi east of the town of Madras in central Oregon. Agoil plans to test pre-Tertiary marine rocks with this 5,500-ft hole.



Northwest Natural Gas started drilling this 2,000 ft thermal gradient hole on the southwest flank of Mt. Hood during June. This is the third geothermal test hole they have drilled in the area.

Current oil, gas, and geothermal exploratory drilling

Mobil reached a depth of 7,000 ft in June with its "Ira Baker No. 1," located approximately 14 mi north of Eugene. The company plans to test Tertiary marine formations to a depth of 11,000 ft at this location.

ABSTRACTS

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

ENVIRONMENTAL GEOLOGY OF THE KELLOGG CREEK-MT. SCOTT CREEK AND LOWER CLACKAMAS RIVER DRAINAGE AREAS, NORTHWESTERN CLACKAMAS COUNTY, OREGON,* by Matthew John Brunengo (M.S. in Geology, Stanford University, 1978)

The study area (approximately 31 mi^2) is located in an "urban fringe" zone southeast of Portland, Oregon, and includes all or parts of the incorporated cities of Milwaukie, Gladstone, Happy Valley, and Johnson City, and the towns of Clackamas, Sunnyside, and Park Place. This region has undergone explosive growth in the last decade and will continue to be developed in the coming years. Such growth will require careful evaluation of the physical limitations imposed on development by the topography, geology, climate, and hydrology of the area.

The geologic units of the area are the Yakima Basalt (Miocene), Sandy River Mudstone (Pliocene), Troutdale Formation (Pliocene), Boring Lava (Pliocene-Pleistocene), and Quaternary fluvial sands and gravels. The fluvial deposits have been cut into multiple terrace levels, which are here called the Gresham, Portland, Estacada, and Lower Clackamas terraces (in order of decreasing elevation and age). The geologic structure is dominated by the Portland Hills Fault: southwest of the fault is the uplifted Oatfield Ridge block, and northeast of it is the sediment-filled Portland basin. Sand and gravel are mined from most of the Quaternary fluvial units, and basalt is quarried from the Yakima Basalt.

An understanding of surficial processes is important in the prediction of environmental limitations on development. The magnitudes and effects of storm precipitation, evapotranspiration, soil infiltration, ground-water occurrence and quality, runoff production, stream behavior and erosion, flooding, soil erosion, and mass movement are discussed, with emphasis on their relevance to the study area, and on the effects of urbanization on the processes. Flooding is the most important geologic hazard in the area, but landslides, soil erosion, and streambank erosion also take place, and much of the area suffers from poor infiltration and ponding.

As a framework for discussion of the environmental geology of specific areas, the study region is divided into environmental systems and units on the basis of common materials, landforms, and processes. These are the Oatfield Ridge system (basaltic and gravel units), the Mt. Scott-Clackamas Heights Uplands system (upper slopes and lower slopes units), the Portland Terrace system, the Lowlands system (Estacada surface, terrace depressions, well-drained surfaces, depressions and drainageways, organic soils, and river gravels units), and the Terrace Scarps system. For each of these units, the soils, land use limitations, and geologic hazards are discussed and tabulated.

The study area is within a region of moderate to severe earthquake potential. The Portland Hills Fault may be active, and structures in the entire area are subject to damage caused by seismic shaking. Volcanic hazard is minimal.

LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS OF THE COALEDO FORMATION, COOS COUNTY, OREGON, by Paul Thomas Ryberg (M.S. in Geology, University of Oregon, 1978)

The late Eocene Coaledo Formation, which is well exposed along the coast in western Coos County, has been subdivided into several stratigraphic units within each member. Seven types of lithofacies are defined, based on dominant lithology, bedding characterstics, and sedimentary structures.

Petrographic examination of composition and texture in Coaledo sandstones indicates a dominant andesitic volcanic source with minor plutonic, metamorphic, and sedimentary sources. Paleocurrent analysis suggests that this source area was located to the southeast. Sedimentary structures, fossils, and paleocurrents strongly suggest that Coaledo sediments were deposited on a coastline open to the west, i.e. with no restricted embayments.

At least 10 coarsening upward sequences are recognized in the lower Coaledo member, and at least eight are recognized for the upper member. These sequences probably represent prograding deltaic topset deposits, including distributary channel sands, interdistributary tidal flat and lagoonal sediments, and barrier bar sands. Deltaic foreset deposits are probably represented by the upper Elkton (?) interval immediately below the base of the Coaledo, and by the upper part of the middle Coaledo member. Deeper marine conditions are represented by the lower part of the middle Coaledo and the overlying late Eocene Bastendorff Formation.

GEOLOGY OF THE BLUE RIVER MINING DISTRICT, LINN AND LANE COUNTIES, OREGON, by Sara Glen Power Storch (M.S. in Geology, Oregon State University, 1978)

The Blue River Mining District is located in Linn and Lane Counties, Oregon, in the Western Cascades physiographic province. A few small veins in the district have been mined intermittently for gold since 1887, although most activity in the district ceased in 1913.

The volcanic rocks of the district are Miocene in age and belong to the Sardine Formation. Common volcanic lithologies include laharic breccias, lapilli tuffs, water-laid tuffs, basaltic andesites, and a dacite. The basaltic andesites are chemically similar to basalts of the Sardine Formation studied by White (personal communication, 1977) in the North Santiam area.

Intruding the volcanic sequence are small epizonal plutons. These dacite and andesite porphyries are similar to granodioritic and quartz dioritic plutons of island arc environments on the basis of their deficiencies in potassium feldspar and K_2O. The igneous rocks of the Blue River District show similarities with the calc-alkaline rock suite in their increasing K_2O, and decreasing FeO, MgO, CaO, and Al_2O_3 with increasing SiO_2 content, and in their systematic distribution on AFM and NKC diagrams.

Northwest-trending fractures and shear zones formed before and during the intrusive episode and subsequent mineralization. The area was later uplifted and folded to form the broad Breitenbush anticline.

Small U-shaped troughs, cirque-like features, and spines above 4,400 ft indicate that small valley glaciers were active in the district in recent geologic time. Since glaciation, streams have carved steep V-shaped valleys. Landslides and artificially induced subsidence (related to mining activity) have altered the present topography.

Hydrothermal alteration in the district has resulted in large areas of propylitically altered rocks, as well as some restricted areas of phyllic alteration in highly fractured rocks and near veins. Typical propylitic assemblages include chlorite, calcite, epidote, albite, and pyrite. Locally the phyllic assemblage of quartz, sericite, and kaolinite is present in shear zones and wall rock adjacent to veins.

Metallization in the district is restricted to a few small veins and areas of disseminated pyrite. A trace element geochemical survey indicated slightly anomalous metal values in veins and in the more intensely altered areas.

Association of the calc-alkaline magmatism with widespread propylitic alteration, fracture-controlled phyllic alteration, and disseminated pyrite indicates that the Blue River District may overlie a porphyry system at depth which has not been exposed by erosion.

GEOLOGY OF THE AREA NEAR THE NORTH END OF SUMMER LAKE, LAKE COUNTY, OREGON, by Paul Leonard Travis, Jr. (M.S. in Geology, University of Oregon, 1977)

The purpose of the study was to determine the nature and causes of the fault patterns north and east of Summer Lake. Secondarily a gravity survey was conducted to determine the general shape and depth of the valley floor below the alluvium. The Picture Rock Basalt covers most of the surface above the level of the valley floor. It was probably erupted about 10 million years ago. Normal faulting was initiated (or recommenced) shortly thereafter, and both faulting and volcanic activity have continued into the late Quaternary. The pattern of parallel, curved, and locally intersecting faults is primarily the result of inhomogeneous east-west extension, with about 1,500 m of extension having occurred across Summer Lake Valley. Combined with this, there have been lesser amounts of extension in other directions and also some right-lateral shear. The gravity survey shows that the valley fill has a maximum depth of about 2 km and a volume of about 240 km^3. □

Portland DOGAMI offices temporarily moved

The Portland offices of the Oregon Department of Geology and Mineral Industries have been moved temporarily to new quarters in the State Office Building while the old offices are being remodeled. The mailing address is still the same: 1069 State Office Building, Portland, Oregon 97201. The phone number is unchanged: (503) 229-5580.

The State Geologist, Deputy State Geologist, all professional and office staff, cartographer, and editor are now located in Room 408. Turn right after entering Room 408 and look for the receptionist behind the curved desk.

The Business Office, Sales, Shipping and Receiving, and Library are now in Room 555, through the Board of Nursing offices.

People wanting assays or assay information should come to Room 408 or call 229-5580 for further instructions.

Remodeling is expected to take about four months. Be sure to check the Building Directory, first floor of the State Office Building, north wall by the elevators, for our current office numbers. □

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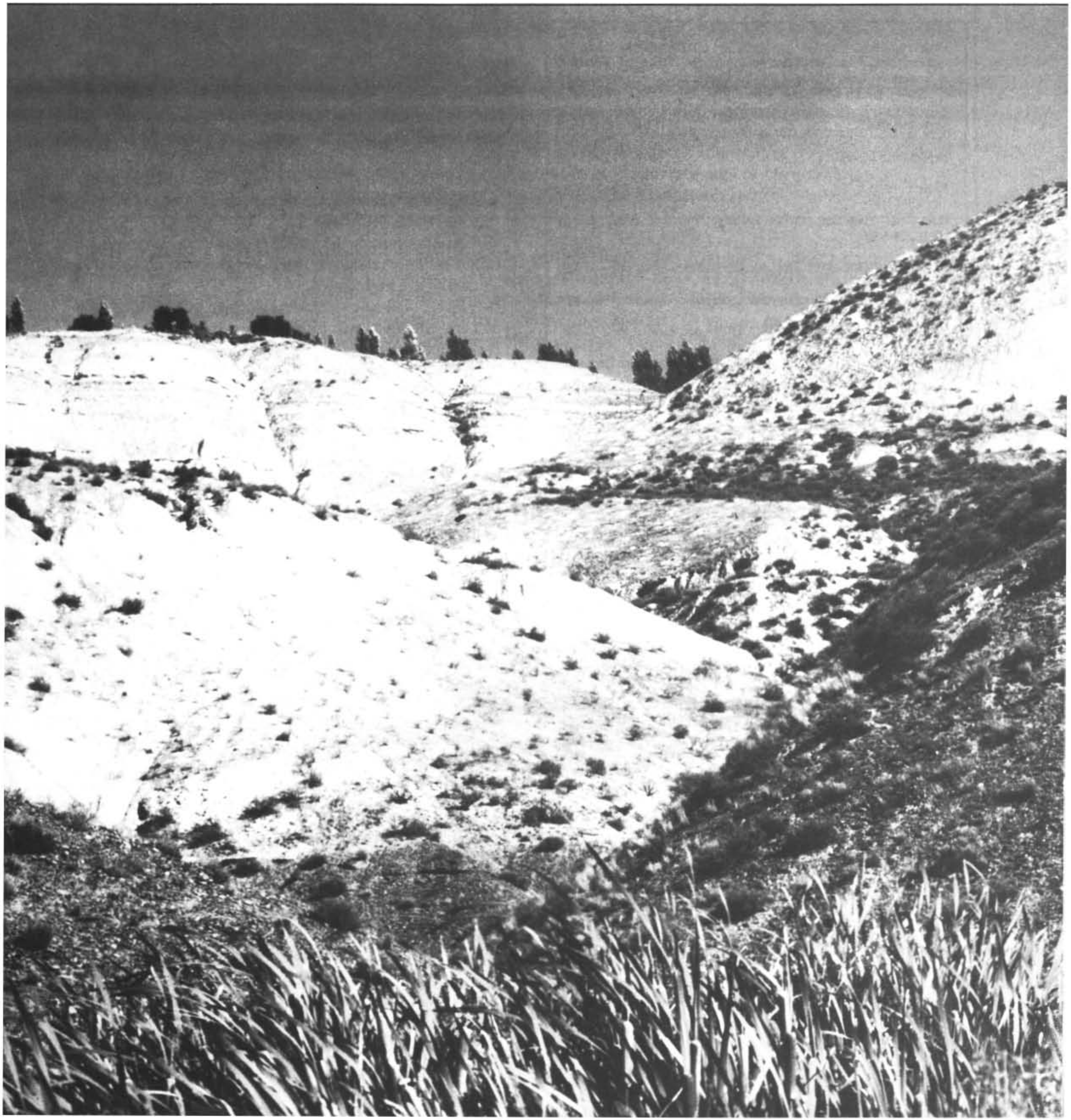

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COVER PHOTO

White Bluffs, type section of the Ringold Formation, exposed along Columbia River in southeastern Washington. These deposits were studied for paleomagnetism. See article beginning on page 119. (Photo courtesy Duane R. Packer, Woodward-Clyde Consultants.)

Friends of Mineralogy to hold fifth annual symposium in September

The Friends of Mineralogy, Northwest Chapter, will hold their fifth annual symposium, "Sulfides and Sulfosalts," September 28 through 30, 1979, at the Bellevue Holiday Inn on Interstate 405 just across the floating bridge from Seattle, Washington. Symposium hours will be 7 p.m. to 11 p.m. Friday, 8 a.m. to 11 p.m. Saturday, and 8 a.m. to 12 a.m. Sunday.

Speakers will be Joseph Mandarino, Curator, Royal Ontario Museum; Les Zeihen, Consulting Mineralogist for the Anaconda Company, Butte, Montana; Robert Cook, Associate Professor of Geology, Auburn University, Auburn, Alabama; Joe Nagel and Colin Goodwin, University of British Columbia, Vancouver, B.C., Canada; and Bob Jackson, Collector, Renton, Washington. Lectures will be centered about the theme, "Sulfides and Sulfosalts."

Approximately 10 to 20 noncompetitive, educational exhibits related to finely crystallized sulfides and sulfosalts are anticipated.

Three well-known dealers, Nature's Treasures, The Mineral Mailbox, and Lidstroms, will be represented at the symposium.

The Saturday evening symposium will be informal and devoted to trading, examining dealers' minerals, attending microscope and mineral workshops, and socializing.

Additional information about the symposium can be obtained from Mike Groben, Rt. 1, Box 16, Coos Bay, Oregon 97420; phone: (503) 269-9032. □

CONTENTS

Paleomagnetism and age dating of the Ringold Formation and loess deposits in the State of Washington

by Duane R. Packer, Senior Project Geologist, Woodward-Clyde Consultants, Three Embarcadero Center, Suite 700, San Francisco, California 94111

Holocene, Pleistocene, and Pliocene geologic units in Oregon and Washington commonly display similar lithologies over large areas. Yet, inquiry into the nature of the units is becoming increasingly precise as we probe their meaning in terms of recent faulting and tectonism.

Paleomagnetism is one of several technologies now being used to increase our understanding of these units. Woodward-Clyde Consultants, under contract to the Washington Public Power Supply System, used paleomagnetic techniques to help establish the age of the Ringold Formation in southeastern Washington and Craigs Hill loess deposits at Ellensburg, Washington. This article describes types of techniques that may be applicable in addressing the poorly understood late Cenozoic geology, both in Washington and in Oregon.

All artwork and photographs are courtesy of Woodward-Clyde Consultants.

PALEOMAGNETISM

Introduction

Paleomagnetism is a useful tool for determining the dates of formation of sedimentary and igneous rocks. The application of paleomagnetism is based on the fact that rocks record the direction and intensity of the earth's magnetic field during their formation and retain this magnetic information for thousands to billions of years. The age-dating aspect of paleomagnetism takes advantage of the fact that the earth's magnetic field is dynamic and has undergone a number of distinctive changes in the geologic past.

The record of these changes can be used to date geologic materials. The most easily recognized of all these changes is a reversal of the earth's magnetic field, which has occurred many times in the geologic history of the earth. The last major reversal occurred 700,000 years ago (Figure 1).

Theory

The earth's magnetic field undergoes various changes in both intensity and direction over periods of time ranging from nanoseconds to millions of years. Reversals of the polarity of the earth's field, on which magnetostratigraphy is based, appear to have occurred randomly in the geologic past and are recorded in rocks worldwide. Complete reversals having durations on the order of 10^5 years are called magnetic polarity epochs. Complete reversals having durations on the order of 10^3 to 10^4 years are known as events. Significant changes in magnetic pole position, but not complete reversals, having durations on the order of 10^3 years are called magnetic excursions.

All of these magnetic phenomena have potential for use in dating, but polarity epochs and some events are the best dated and documented in geologic sections throughout the world. Other changes in declination and inclination (the magnetic azimuth and dip, respectively), called secular variations, take place on a continental scale and have durations of 10^2 to 10^3 years. These changes have application to dating in specific geographic areas such as Europe, where the known magnetic record over the past several thousand years includes secular variations. In other areas, the secular variation pattern could potentially be developed and applied to correlation problems.

Basically, paleomagnetism can be used to detect latitudinal movements relative to the earth's field, rotations about vertical and horizontal axes, and relative stratigraphic position in the magnetostratigraphic record. The application of paleomagnetic studies that has the greatest potential in engineering geology is based largely on magnetostratigraphy, which can be used as a relative age-dating and stratigraphic correlation tool in detecting and dating possible fault displacements in time-stratigraphic horizons.

Individual paleomagnetic polarity zones in themselves do not have unique characteristics that allow identification of, for example, an older normal zone from a younger normal zone. Therefore, some bracketing age data (paleontologic or radiometric), as well as a moderately continuous geologic section, are usually required as a basis for identifying the general age of the paleomagnetic zones.

Paleomagnetism is based on the characteristic ability of magnetic minerals to record and retain, in some cases on the order of billions of years, the magnetic field in which they were formed. This property is called natural remanent magnetization (NRM). One way in which NRM is acquired is by thermal rem-

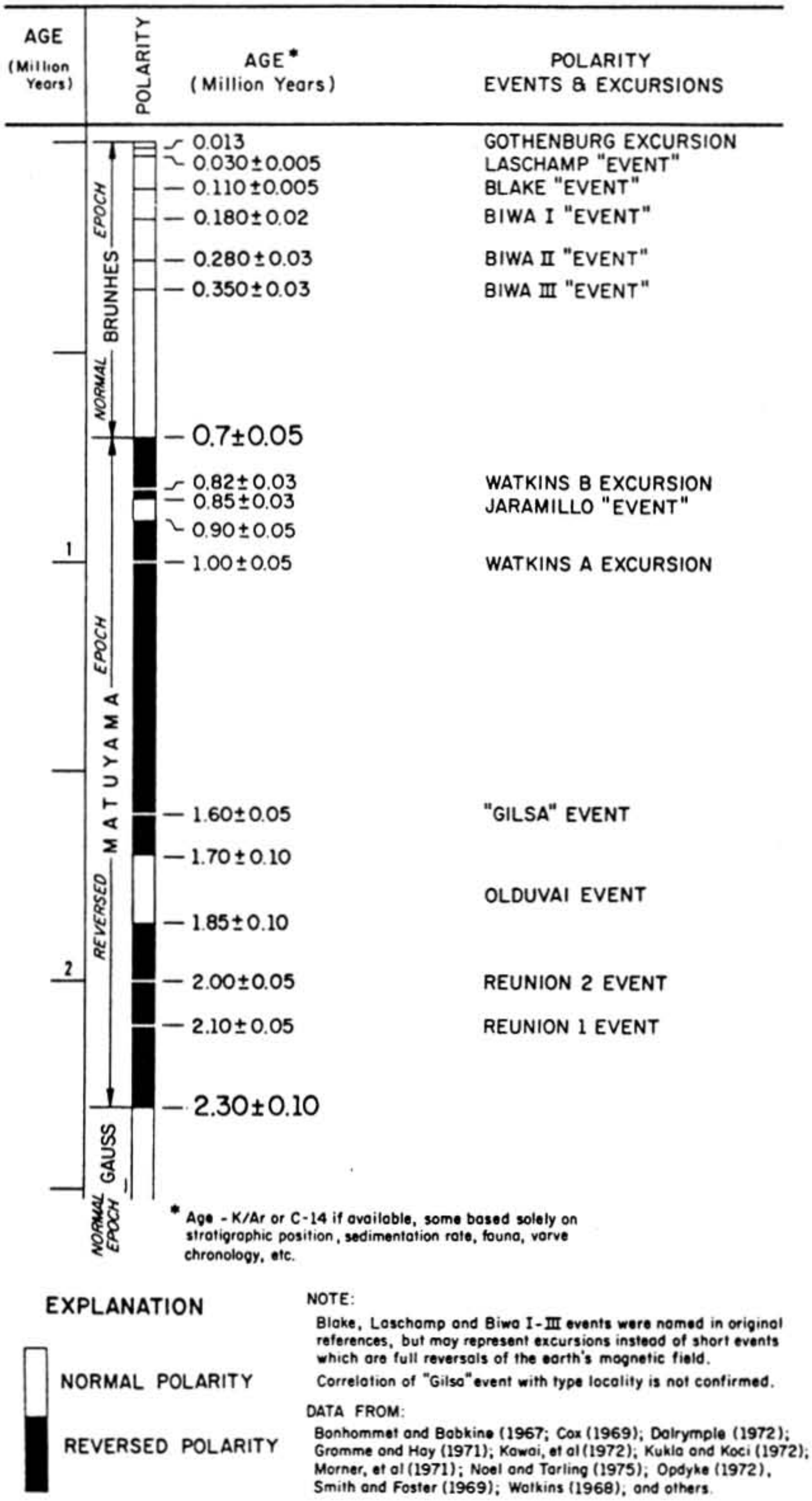


Figure 1. Magnetostratigraphy for the last 2.5 million years.

anent magnetization (TRM). A magnetic mineral acquires its magnetization as it cools through its Curie point, the temperature at which the atomic and molecular thermal energy become sufficiently low that the spin directions and magnetic moments become locked along the ambient field direction. Natural remanent magnetization in rocks is also dependent on many other factors, including crystal structure and crystal size.

Rocks can also acquire NRM by detrital remanent magnetization (DRM) and by chemical remanent magnetization (CRM). DRM is acquired by sedimentary magnetic particles aligning as small compass needles along the direction of the earth's magnetic field. CRM involves the oxidation or reduction of iron minerals, forming secondary minerals such as hematite, magnetite, or titano-magnetite. During their formation, these minerals record the direction of the earth's magnetic field. It is by this CRM process, for example, that red beds acquire their magnetization. Although it is a secondary magnetization, it is usually assumed to have occurred very close to the time of the formation of the rock and is therefore a record of the field at that time.

Many other secondary factors, including viscous remanent magnetization (VRM) and anhysteritic remanent magnetization (ARM), may have disturbed the original NRM in a rock. A large part of a paleomagnetic analysis therefore is directed at discovering and removing or correcting for disturbances to the original NRM direction. Two techniques are commonly used for this process: alternating field demagnetization and thermal demagnetization. It is not always possible to correct for magnetic disturbances, and some samples may yield no useful information about their original NRM direction. However, the effect of such samples can be discounted because they are usually relatively few and can be detected and isolated during the analysis.

RINGOLD FORMATION AND CRAIGS HILL LOESS

This report presents the results of the preliminary study of the paleomagnetic polarity of the Ringold Formation in the Hanford, Washington, area and two loess deposits in the Ellensburg and Yakima, Washington, areas. The objectives of the preliminary study of the Ringold Formation were to evaluate its magnetic stability and to determine whether or not it contains a polarity sequence suitable for age dating and correlation. Samples from approximately 120 m (400 ft) of silts and sands were collected from a section extending from a basal contact with a conglomerate up to a caliche cap and overlying loess. The section, the type section of the Ringold Formation, is exposed in the White Bluffs along the Columbia River in the west half of sec. 25, T. 11 N., R. 28 E. The approximate locations of the upper and lower parts of this section are shown in Figure 2. The cliff-forming unit from which the samples were taken is shown in Figure 3. The section was laterally offset to obtain maximum exposures.

A preliminary study of the paleomagnetic polarity was made of loess deposits overlying the Naneum conglomerate at Craigs Hill in the southern portion of sec. 36, T. 18 N., R. 18 E., at Ellensburg. The objectives of this study were to see if these deposits of loess are magnetically stable and were formed in a reversed magnetic field. Approximately 16 m (50 ft) of section, with samples from 11 stratigraphic levels, were collected at this location. The location of this section is shown in Figure 4.

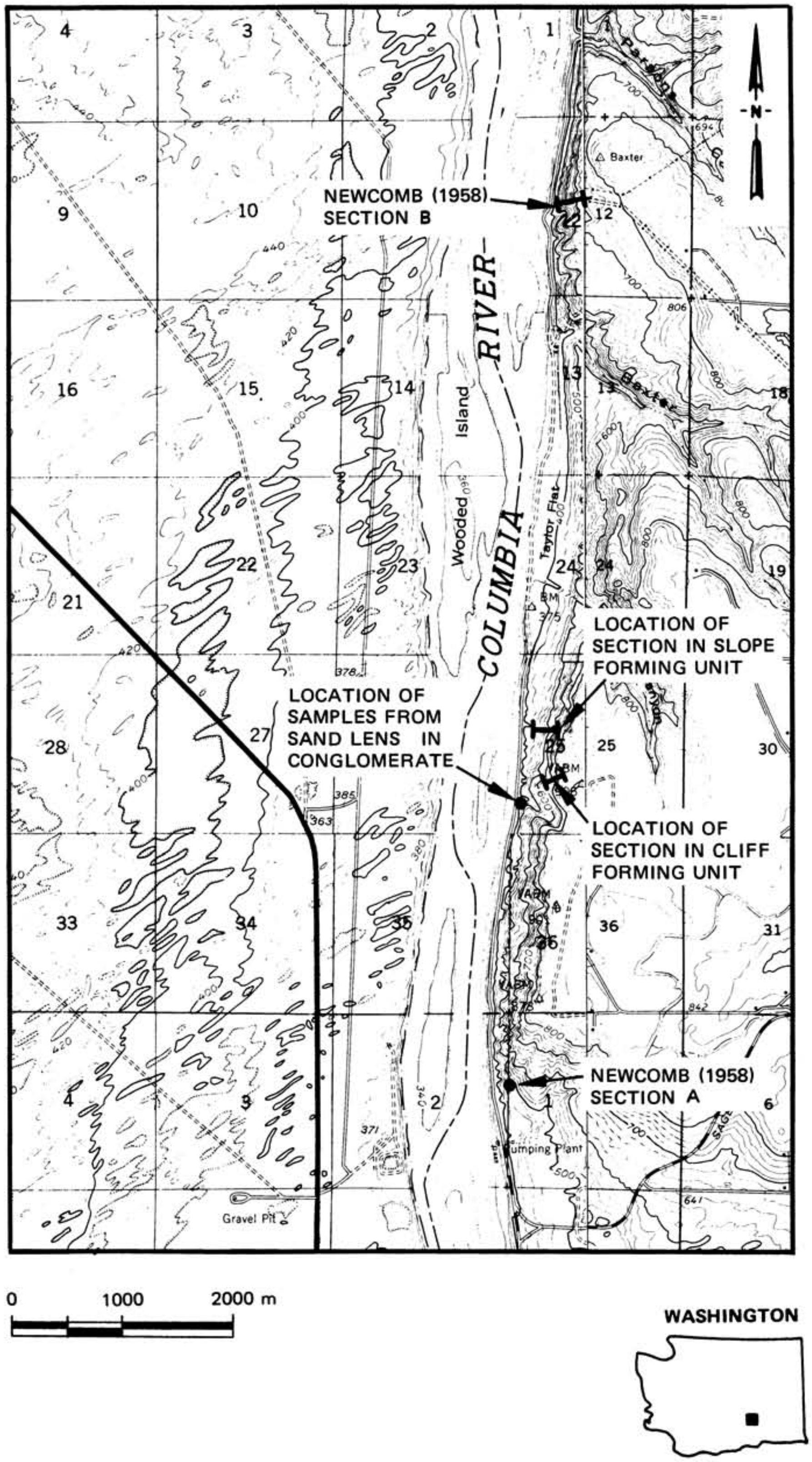


Figure 2. Location map of Ringold Formation section.

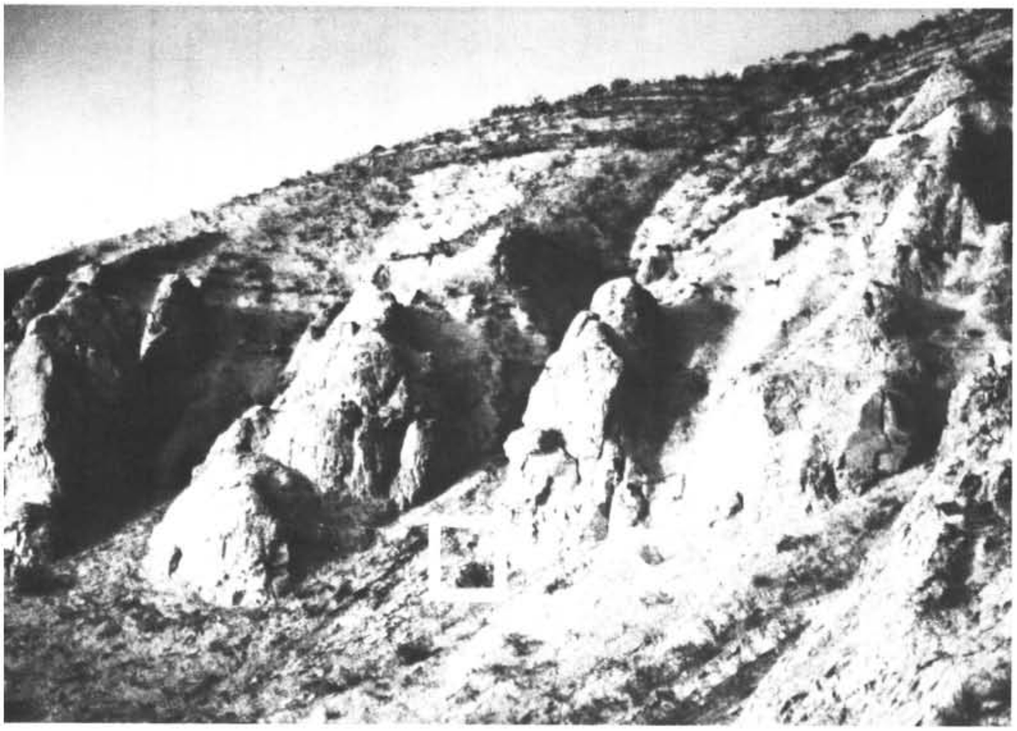


Figure 3a. Ringold Formation section. View to east showing bluffs of cliff-forming unit. Box is area of closeup shown in (b).

Figure 3b. Closeup of base of cliff-forming unit shown in (a). Arrow points to location from which oriented blocks for samples 5 and 6 were collected.

SAMPLE COLLECTION AND ANALYSIS

Paleomagnetic samples for this study were collected by two techniques. The most common technique for friable material was to hand carve a pedestal of the rock to fit into a 5 cm^3 plastic cube. The cube was oriented before removing the sample from the outcrop. The samples were sealed inside the plastic cubes with nonmagnetic fiberglass resin. The remaining samples were collected in oriented blocks from the cemented or consolidated lenses. These blocks were carefully reoriented in the laboratory, and sample cubes were cut from them. The approximate orientation errors for these samples are less than 5 degrees and randomly distributed, which for the purposes of this study do not affect the interpretation of the results.

Two samples were usually collected at each stratigraphic level to compare magnetic signatures as a check on the consistency of magnetization and the magnetic stability of the rock units. An attempt was made to sample at 5- to 7-m (16- to 23-ft) stratigraphic intervals, although for the most part, samples were selectively collected from the more resistant and most unweathered units.

The samples were measured with a superconducting rock magnetometer and were demagnetized in steps in a 400-Hz alternating field (AF) at four or more demagnetization levels. The number of demagnetization levels varied, depending on the magnetic coercivity ranges of the samples. The AF demagnetization unit is magnetically shielded and rotates the samples about three axes during demagnetization. The results of the AF demagnetization provide a means to evaluate the magnetic stability of the section by comparing the relative direction and intensity changes during demagnetization. All data were recorded and computed during measurement by an on-line computer.

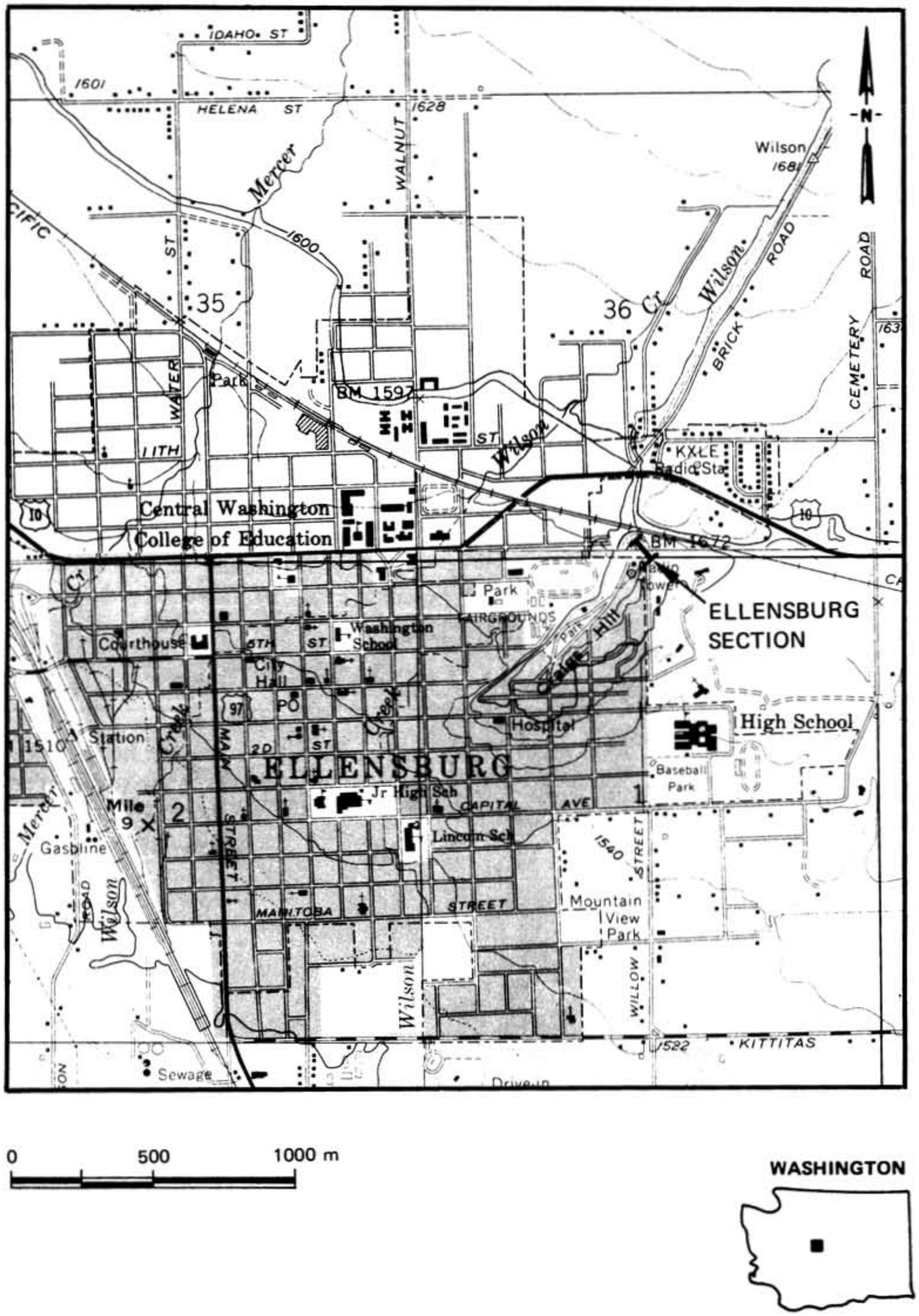
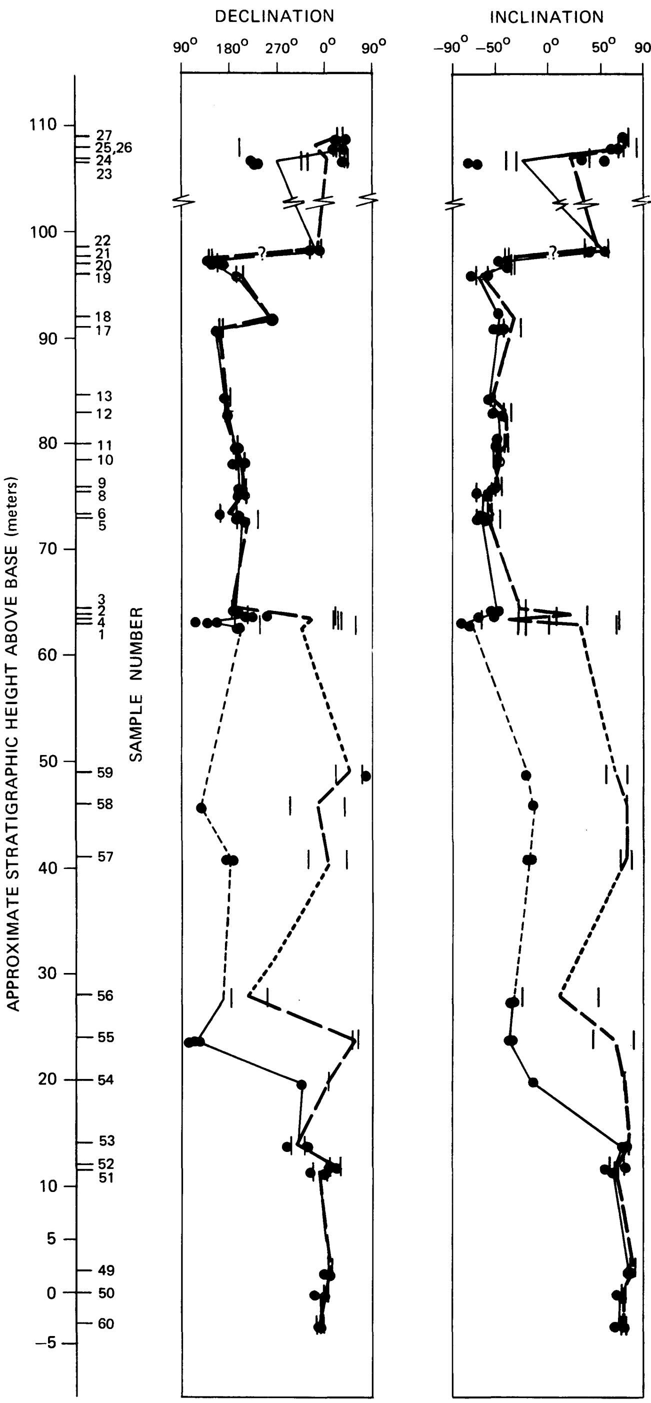


Figure 4. Location map of Craigs Hill loess section, Ellensburg, Washington.



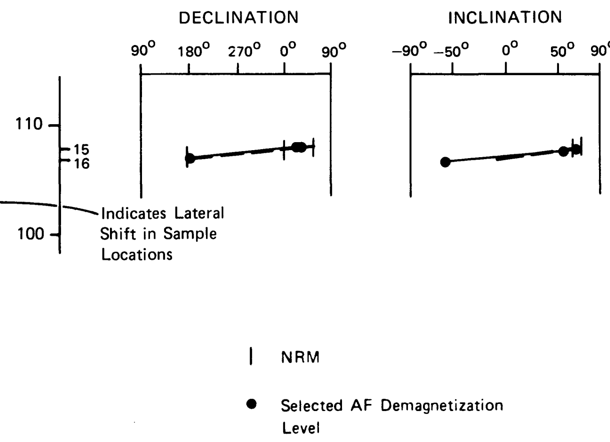


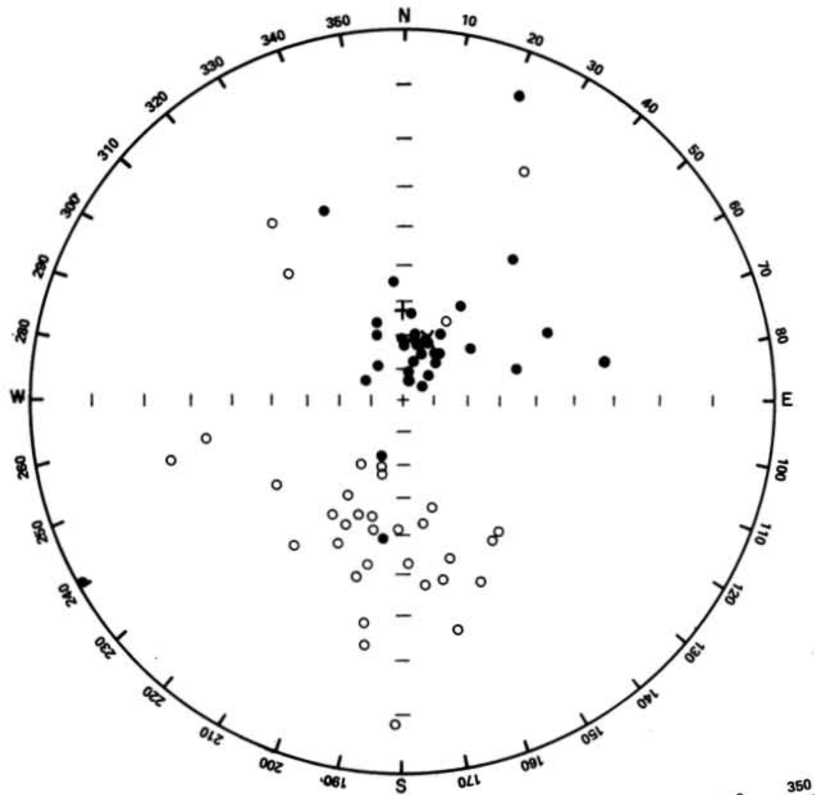
Figure 5. Declination and inclination versus stratigraphic height at Ringold Formation section.

RESULTS

Ringold Formation

Magnetic stability of the Ringold Formation is generally good, based on the relative declination and intensity changes during demagnetization. Of the approximately 37 stratigraphic levels, samples from a portion of the section (40 to 50 m [130 to 160 ft] above the base) had large secondary magnetization overprints. The resultant directions from this portion, although probably representing true polarity, may not represent the original magnetization direction. The variation of declination and inclination with stratigraphic height above the base for both the natural remanent magnetization (NRM) and the selected demagnetization levels are shown in Figure 5. These same results plotted on a stereonet are shown in Figure 6. The improved grouping for both normal and reverse direction after demagnetization further demonstrates magnetic stability.

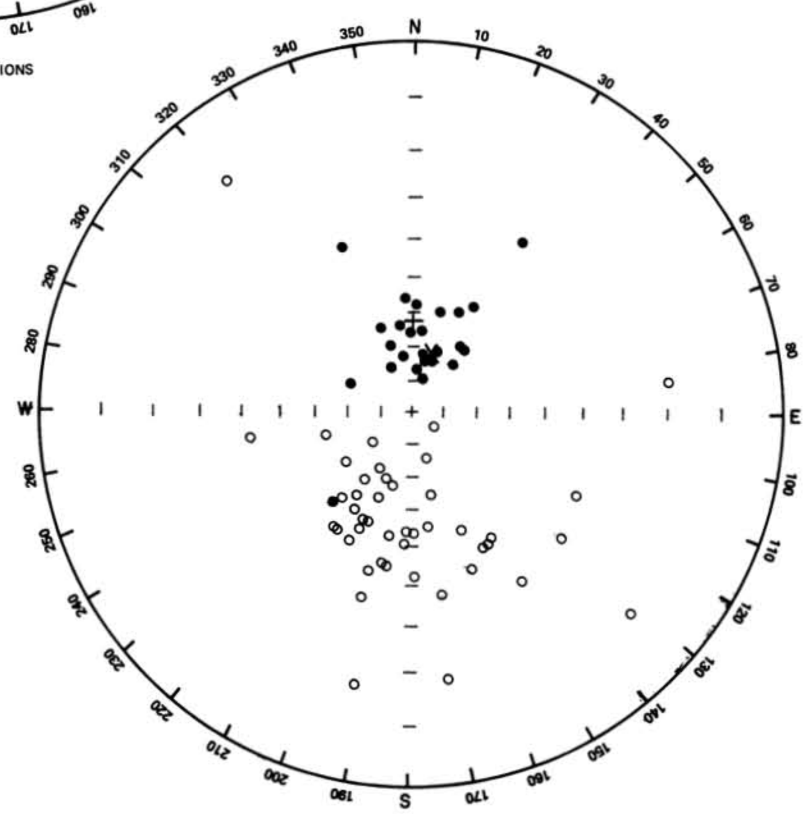
The degree of magnetic stability of this section is also shown by the intensity of magnetization (Figure 7). The magnetization of samples from 70 m (230 ft) and above was more stable than most of the lower section. This part of the section has a consistently higher intensity of magnetization (Figure 7). The most unstable samples are from the part of the section between 40 and 50 m (130 to 160 ft), and they have relatively low magnetic intensities. The weakest NRM intensities were from 2 to 3×10^{-7} emu/cm³ for the ash unit at approximately 65 m (210 ft) above the base of the section.



(a) NRM DIRECTIONS

EXPLANATION

SYMBOLS x AND + ARE THE DIRECTIONS OF THE PRESENT EARTHS FIELD AND THE AXIAL DIPOLE FIELD, RESPECTIVELY, AT THE SAMPLING SITES. PLOTS ARE WULFF (EQUAL ANGLE) STEREONETS; SOLID CIRCLES INDICATE LOWER HEMISPHERE AND OPEN CIRCLES INDICATE UPPER HEMISPHERE.



(b) SELECTED AF DEMAGNETIZATION LEVEL DIRECTIONS

Figure 6. Stereonet plots of magnetization directions at Ringold Formation section.

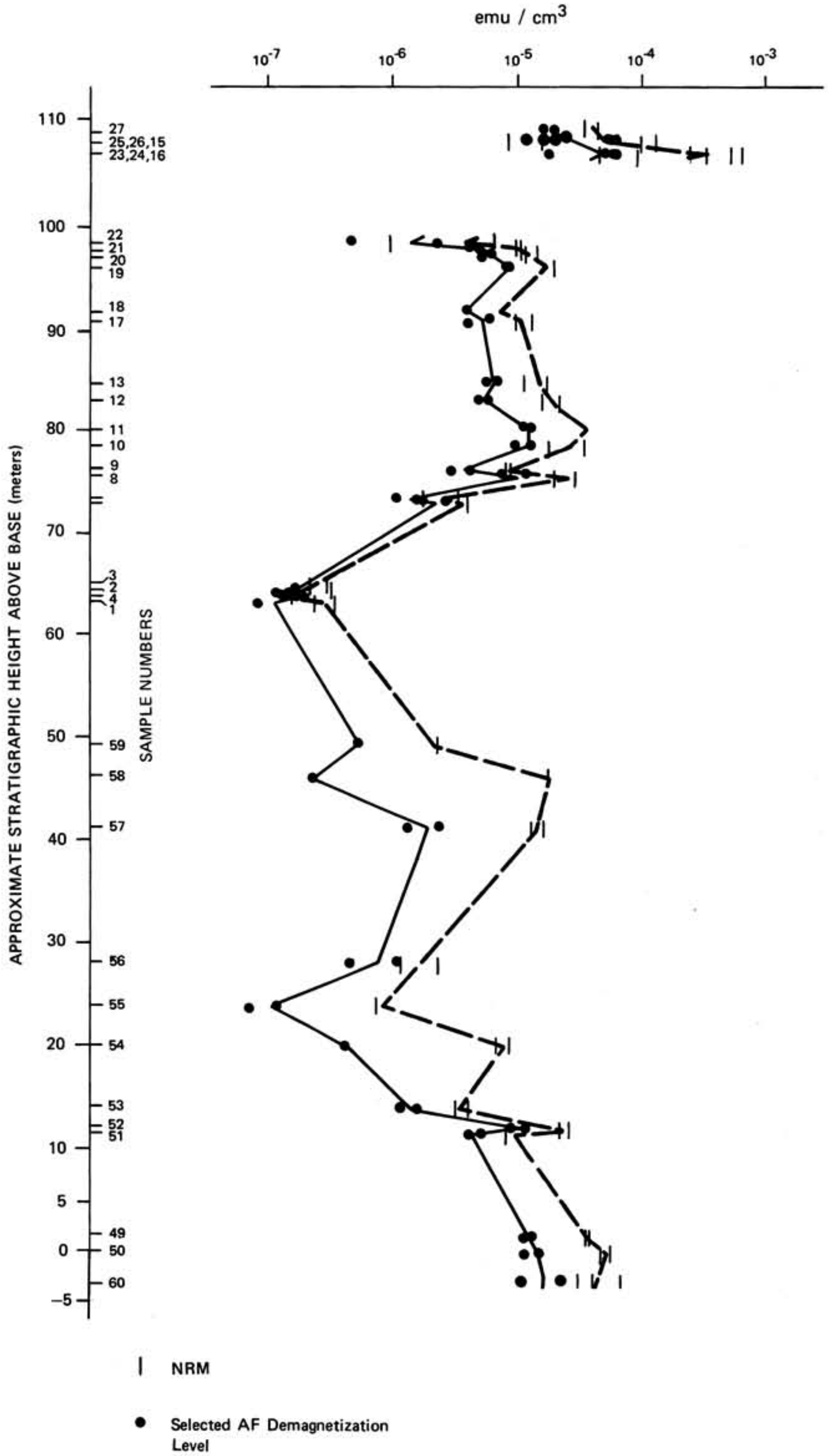


Figure 7. Intensity versus stratigraphic height at Ringold Formation section.

The magnetic polarity for this section of the Ringold Formation is shown in Figures 8 and 9. Figure 8 is a plot of the VGP (Virtual Geomagnetic Pole) latitude versus stratigraphic height above the base with magnetic polarity, and Figure 9 presents the magnetic polarity with a schematic section. The section consists of a loess unit with normal magnetic polarity overlying a reversed magnetic polarity section of the Ringold Formation, which extends from approximately 100 to 25 m (330 to 80 ft) above the base. A possible polarity transition occurs between 25 and 20 m (80 to 65 ft). Below 15 m (50 ft) above the base to a sand lens in the conglomerate, approximately 3 m (10 ft) below the base, the magnetic polarity is normal.

Only three stratigraphic sampling levels were collected between 30 and 60 m (100 to 200 ft), which is inadequate to assess fully the magnetic polarity of this section. However, on the basis of three samples between 40 and 50 m (130 to 160 ft), it is probable that the part of the section between 30 and 60 m (100 to 200 ft) is also of reversed magnetic polarity.

Sample level 22 has apparently normal magnetic polarity. This sample was collected at the top of the reversely polarized part of the Ringold Formation. Samples of the Ringold Formation and caliche cap collected several hundred feet laterally and a few feet stratigraphically above sample 22 have normal magnetic polarities. Further samples from this and adjacent sections at closer spacings will be required to determine whether or not a normal polarity exists at the very top of the exposed Ringold Formation in this section.

Craigs Hill loess deposits

Previous paleomagnetic work has shown that the loess deposits that overlie the Naneum conglomerate on Craigs Hill have reversed magnetic polarity (R.D. Bentley, personal communication). Based on direction and intensity change during AF demagnetization, magnetic stability of samples from 11 stratigraphic levels from this site was good. One sample level, level 38, showed a large secondary magnetization component, and samples from level 40 had some secondary magnetization. This secondary magnetization was removed at approximately 100 oersteds. The inclination and declination of these samples versus approximate stratigraphic height above base are shown in Figure 10. The directions of magnetization of these samples are shown also on a stereonet plot in Figure 11. A comparison of the grouping of directions at NRM and after AF demagnetization shows the good magnetic stability after removal of secondary magnetization components. The NRM intensity of magnetization of these samples ranges from 2×10^{-5} to 1×10^{-4} emu/cm^3 after AF demagnetization (Figure 12).

The VGP latitude and polarity of samples from the Craigs Hill loess section are shown in Figure 13. Approximately the lower 3 m (10 ft) of the section has reversed magnetic polarity, and the portion of the section above approximately 4¼ m (14 ft) has normal magnetic polarity. At this location, at least three loess depositional units have been mapped (R.D. Bentley, personal communication). However, on the basis of examination during collection, it was not possible to distinguish more than an upper and lower unit. A photograph of the lower portion of the upper unit is shown in Figure 14. The lower unit, which represents the lower 3 m (10 ft) of the section, has reversed magnetic polarity.

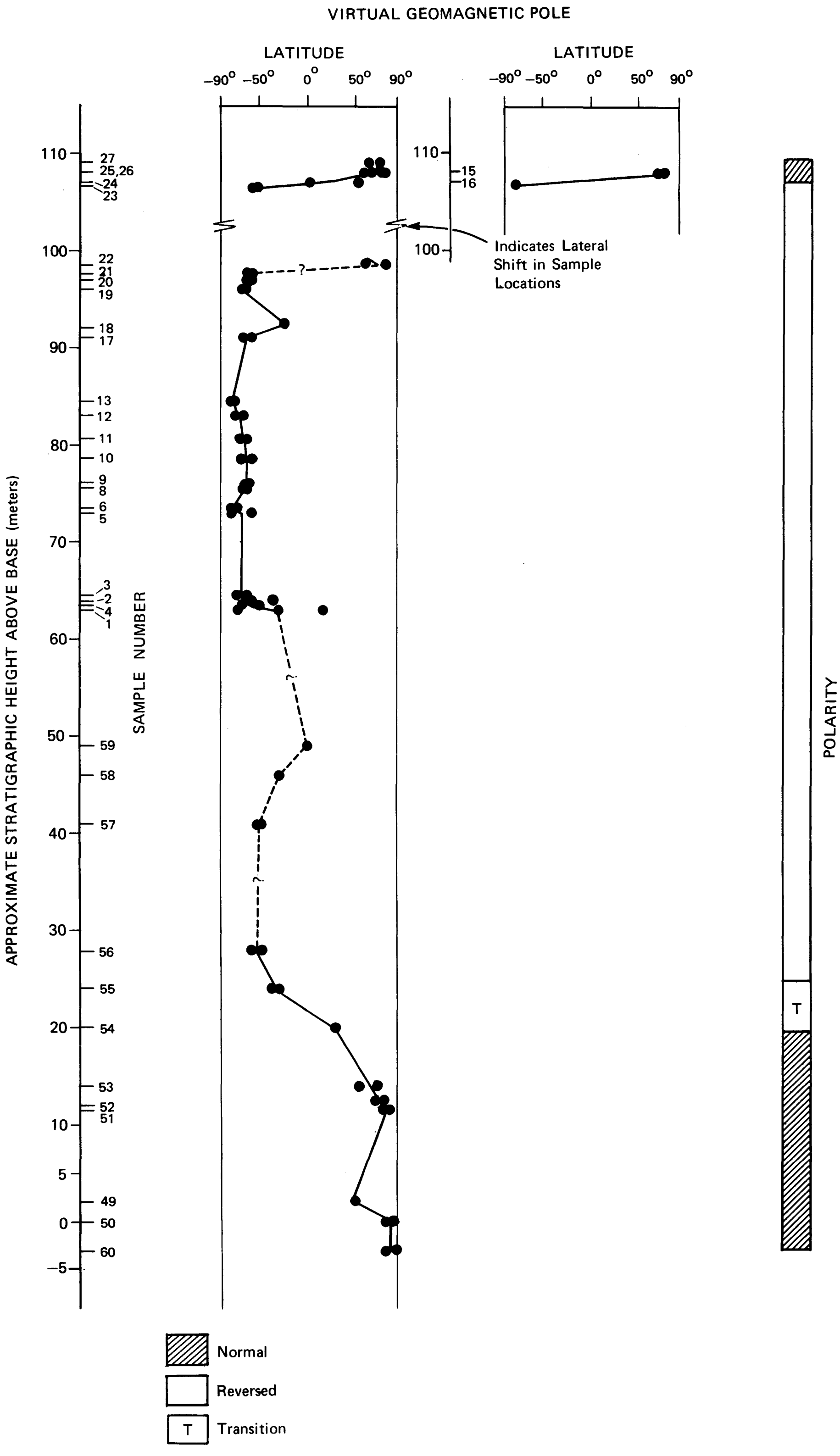


Figure 8. VPG latitude and magnetic polarity versus stratigraphic height at Ringold Formation section.

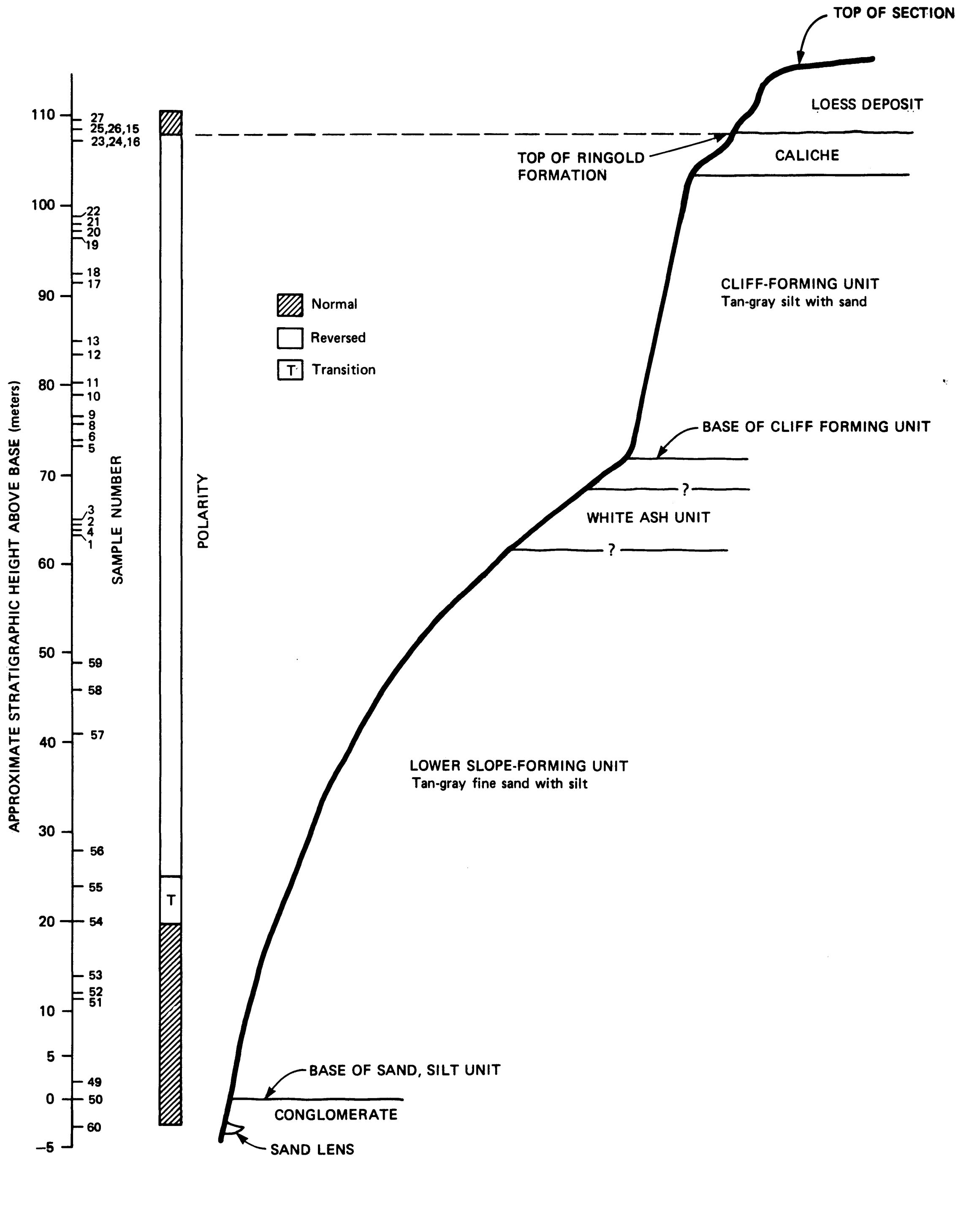


Figure 9. Schematic section with magnetic polarity at Ringold Formation.

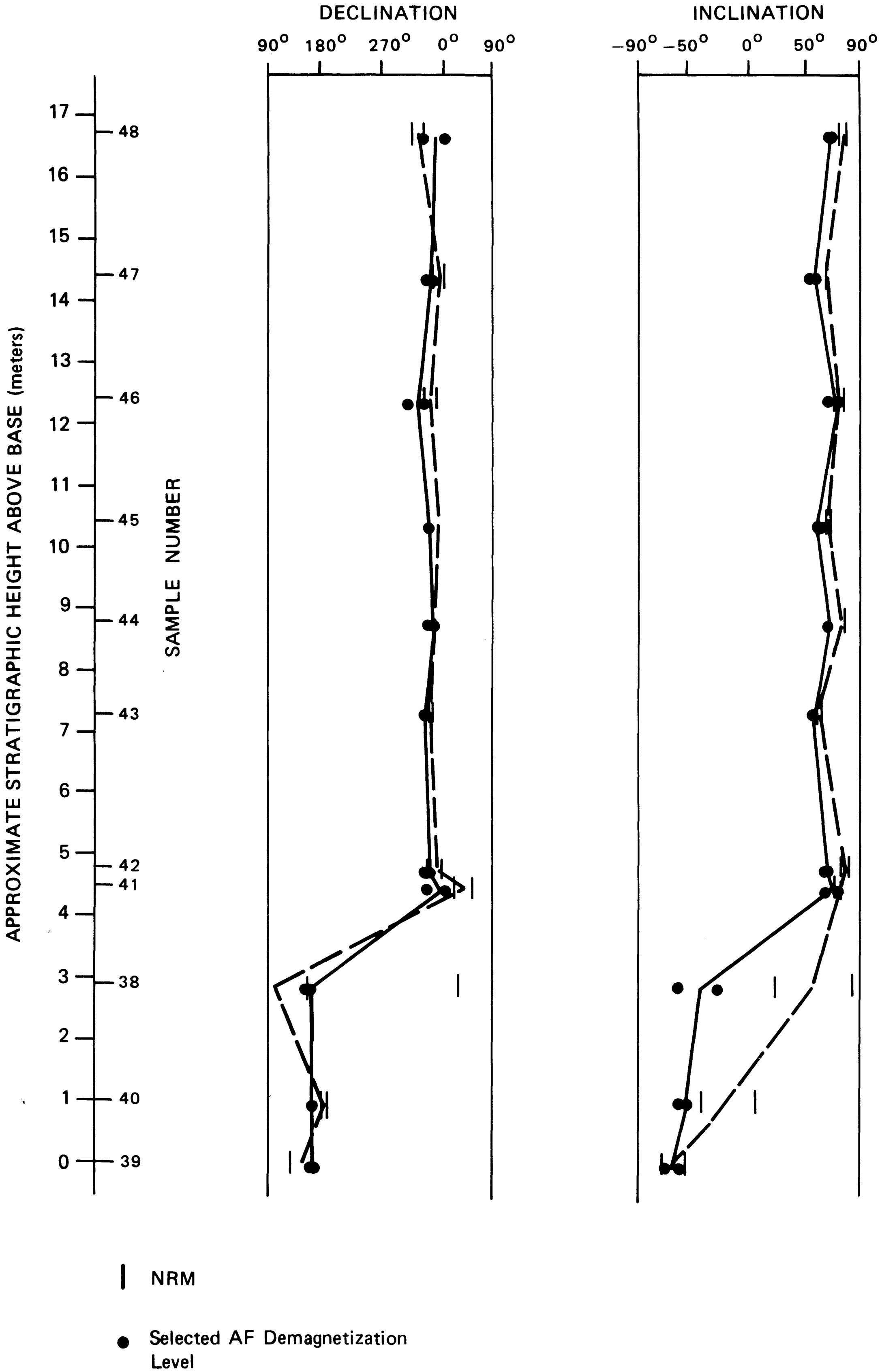
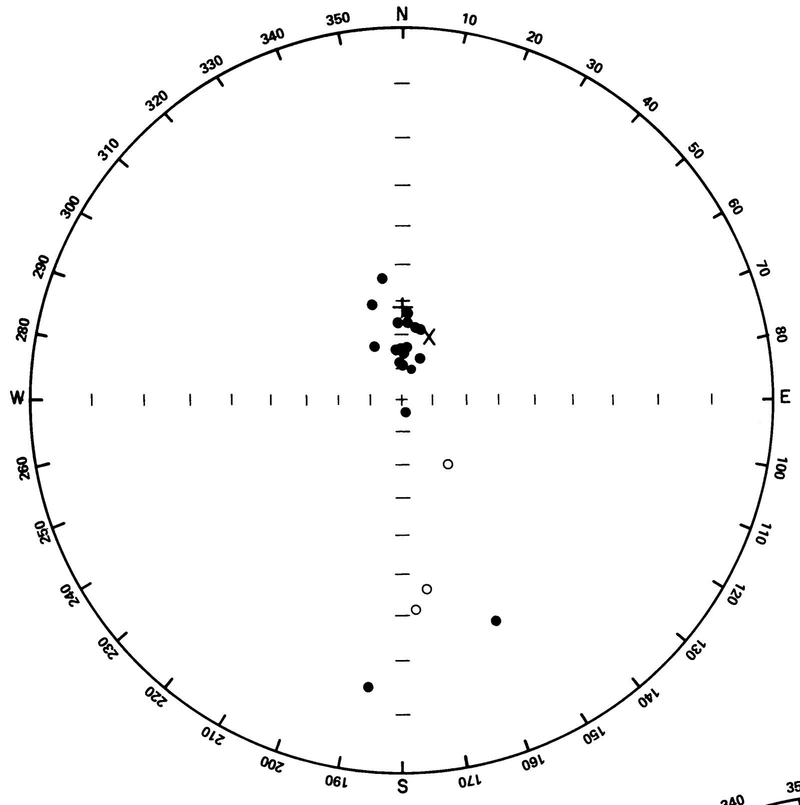


Figure 10. Declination and inclination versus stratigraphic height at Craigs Hill loess section.



EXPLANATION

SYMBOLS x AND + ARE THE DIRECTIONS OF THE PRESENT EARTH'S FIELD AND THE AXIAL DIPOLE FIELD, RESPECTIVELY, AT THE SAMPLING SITES. PLOTS ARE WULFF STEREONETS; SOLID CIRCLES INDICATE LOWER HEMISPHERE AND OPEN CIRCLES INDICATE UPPER HEMISPHERE.

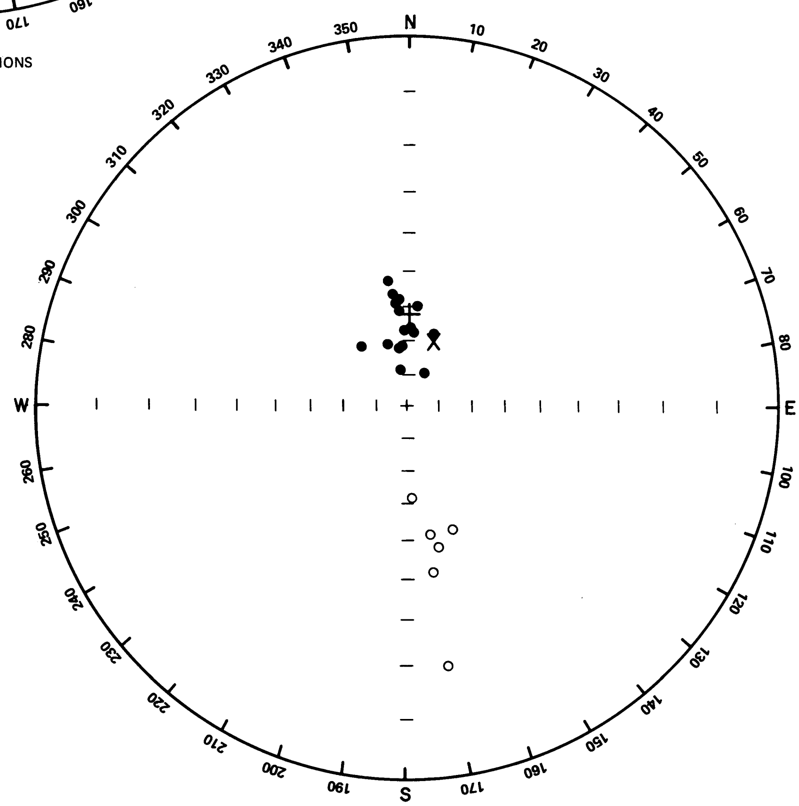


Figure 11. Stereonet plots of magnetization directions at Craigs Hill loess section.

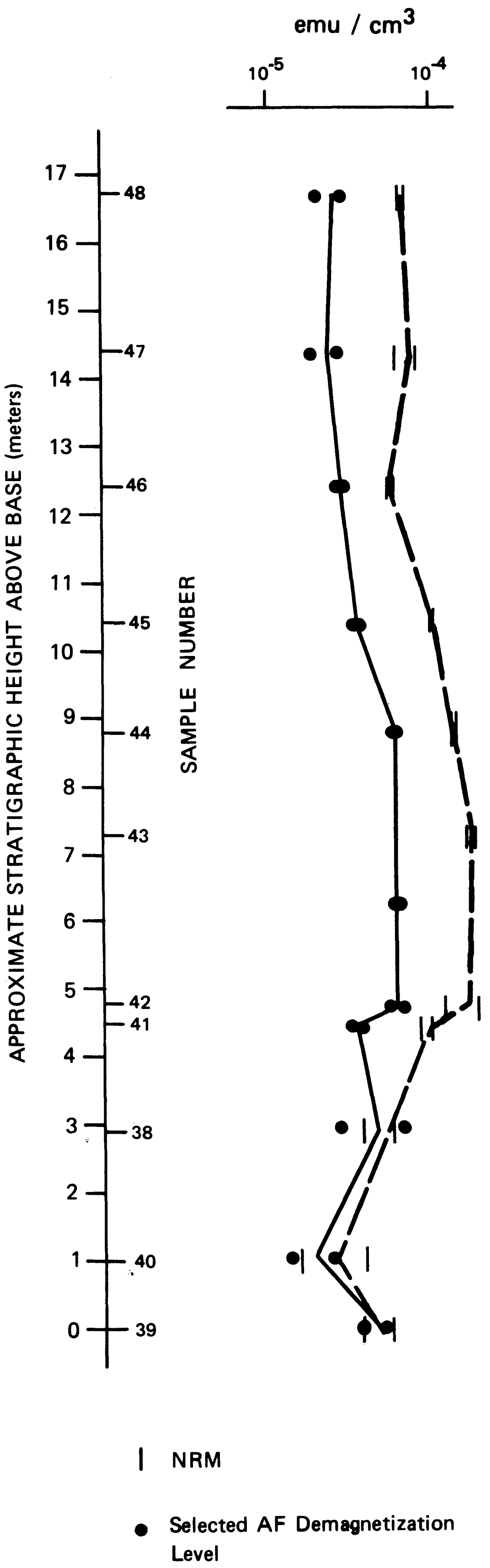


Figure 12. Intensity versus stratigraphic height at Craigs Hill loess section.

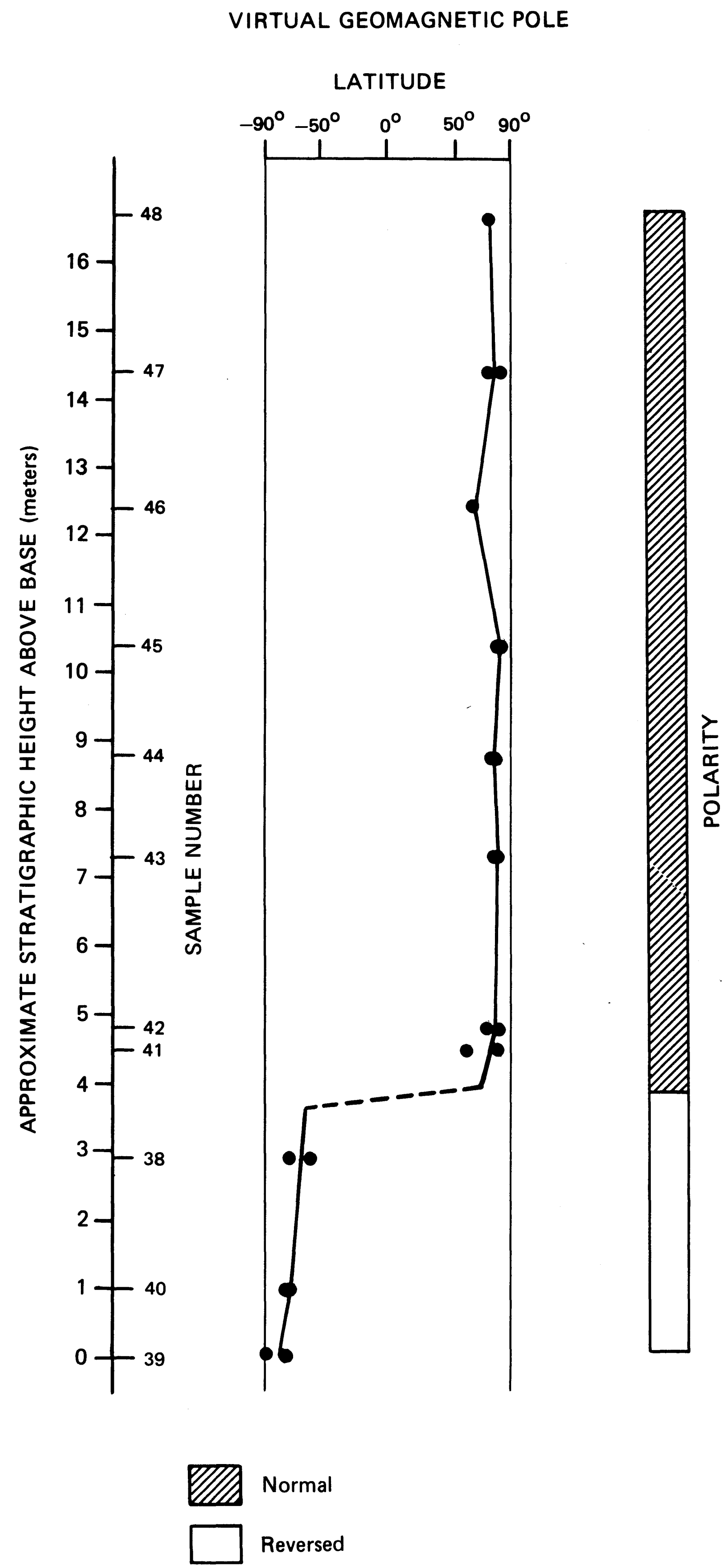


Figure 13. VPG latitude and magnetic polarity versus stratigraphic height at Craigs Hill loess section.

Figure 14. Part of Craigs Hill loess section. Arrows indicate location of oriented blocks collected for samples 41 (lowest), 42 (middle), and 43 (top). Sample 38, the uppermost sample with reversed magnetic polarity, is approximately 1.6 m (5.3 ft) stratigraphically below sample 41.

CONCLUSIONS

Ringold Formation

On the basis of these preliminary studies, the Ringold Formation exposed in White Bluff has been shown to be magnetically stable and to contain a polarity sequence suitable for correlation and possible age dating. The stratigraphically thick, magnetically reversed section confirms that the age of the Ringold Formation is older than 700,000 years.

Craigs Hill loess deposits

The loess deposits overlying the Naneum conglomerate on Craigs Hill have good magnetic stability. The lowest loess unit, approximately 3 m (10 ft) thick, was deposited during a time when the earth's magnetic field was reversed. On the basis of this magnetically reversed section, the deposits in the lower portion of the section are older than 700,000 years.

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Watkins, N.D., 1968, Short-period geomagnetic polarity events in deep-sea sedimentary cores: Earth and Planetary Science Letters, v. 4, p. 341-349. □

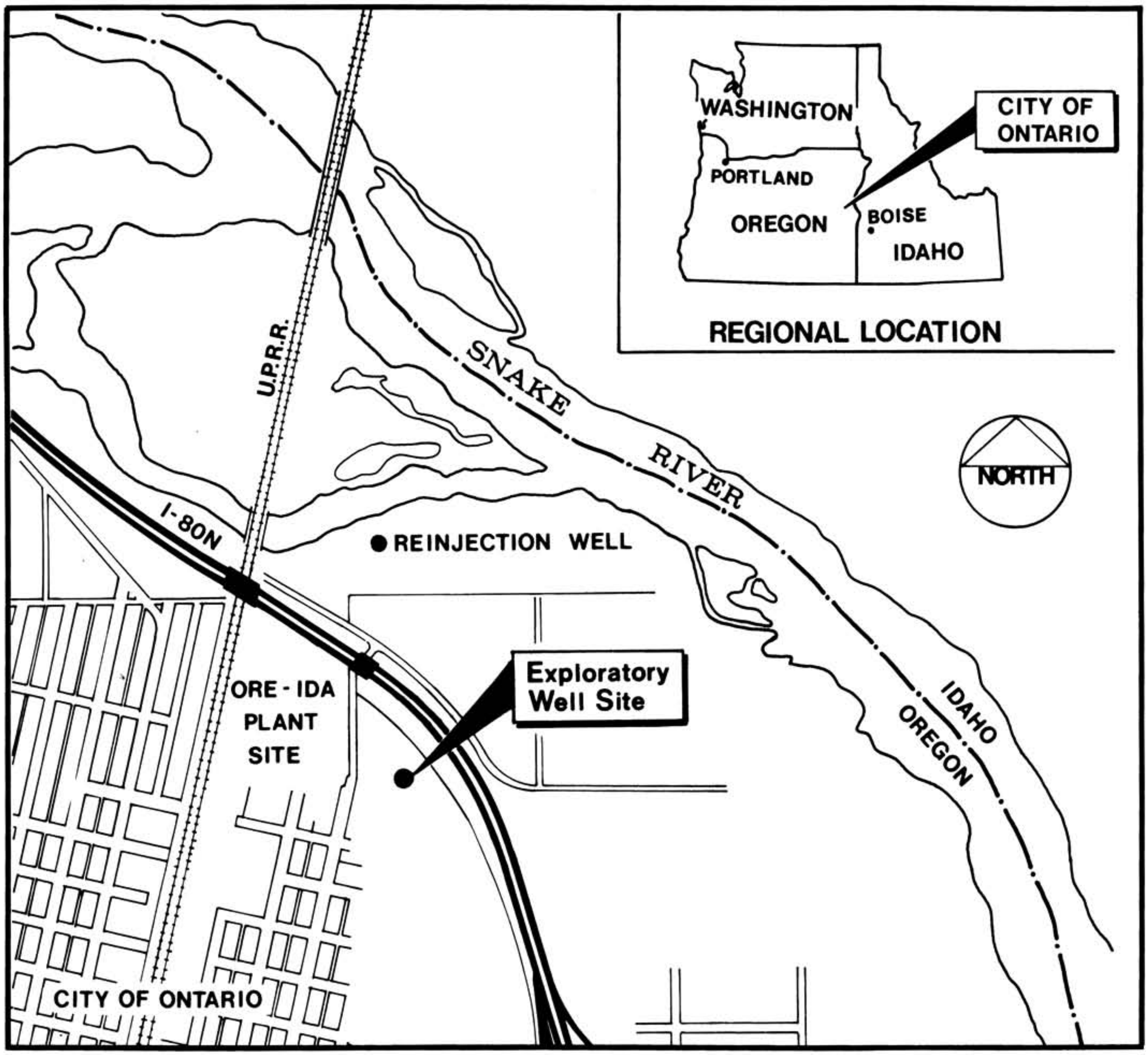
Ore-Ida to begin geothermal exploration

Earlier this year, Ore-Ida Foods, Inc., and the U.S. Department of Energy agreed to jointly participate in a geothermal resource project to use geothermal fluid to substitute for fossil fuel at Ore-Ida's Ontario, Oregon, plant. A contract was signed by Ore-Ida and Perryman Drilling Company, Inc., of Sacramento, California, for drilling a geothermal well in Ontario.

The first exploratory well will be drilled on Ore-Ida property, east of the frozen-food processing plant and northeast of the city. After extensive geologic surveys and analyses, the site was selected as having the necessary heat potential. The temperature of the geothermal fluid is expected to be about 300° to 320°F.

The drilling, set to begin in mid-July, is expected to be completed by late August or early September. "If initial drilling indicates a suitable resource availability, one to two additional wells will be drilled, and equipment at the plant will be mechanically retrofitted to use the geothermal water," said Bob Rolf, Program Manager for Ore-Ida.

Perryman Drilling Company, Inc., was chosen from five bidders on the project. Technical aspects of the program are being managed by CH2M Hill, located in Boise, Idaho. Development of the entire geothermal energy system will occur over a three-year period. □



Locating yourself with the PP&L power pole numbering system*

For years, geologists and other people roaming both on and off the beaten track have used the pole numbering system of Pacific Power and Light Company (PP&L) to find their ways through the hinterlands or to locate specific places on maps. An article in last month's *Oregon Geology* (v. 41, no. 7, p. 108) used a power pole number to indicate the location of a limestone outcrop.

Although this method may not be as precise as some of the more sophisticated navigational techniques now available, it still makes it possible to locate a PP&L pole (and yourself) to within a few hundred feet on any survey map by the information given on the yellow pole tag, which is found within a few feet of the bottom of the pole.

The PP&L pole numbering system is based on the U.S. Public Land Survey Township and Range System, in which a square 6 mi on a side forms the basic unit, called a "township." Townships are laid out north and south from an east-west base line, and east and west from a north-south principal meridian. Parallel lines at 6-mi intervals north and south of the base line are called "township lines"; parallel lines east and west of the principal meridian are called "range lines."

For Oregon and Washington, the base line is the Willamette Base Line, at 45°31′ latitude; the principal meridian is the Willamette Meridian, at 122°44′ longitude. These two lines intersect in Portland's West Hills at the Willamette Stone, which is the point from which early-day surveyors laid out the Oregon and Washington land survey system. In Oregon, township lines are described as north or south of the Willamette Base Line; range lines are east or west of the Willamette Meridian.

PP&L yellow power pole tag. The two sets of figures in the top row indicate township and range. The three sets of numbers in the bottom row tell the section, PP&L grid number, and the pole number within the grid.

These lines intersect to form townships. Each township is divided into 36 sections, each 1 mi square. Sections are numbered consecutively, beginning with 1 in the upper right-hand corner, then going from right to left in the first row, left to right in the second row, and so on, with odd-numbered rows going from right to left and even-numbered rows going from left to right. The last number, 36, is in the lower right-hand corner.

PP&L further divides each section into a grid whose lines form 100 squares, each one-tenth of a mile (528 ft) on a side. The last numbers on a power pole show its position within the square.

The PP&L power pole tag number gives the township, range, section, PP&L grid square, and pole number within the grid square.

How does the system work? The pole number is in two rows, with four digits in the top row and six in the bottom. As an example, assume the top row reads "2513" and the bottom row "172002" and the pole is southwest of Portland in the town of Coos Bay.

The top row tells the township and range. Because the pole is south of the Willamette Base Line and west of the Willamette Meridian, we know already that the township will be south and the range will be west. The 25 means Township 25 South, telling us that the pole is 25 townships or 150 mi (25 townships multiplied by 6 mi per township) south of the Willamette Base Line. The 13 indicates Range 13 West, meaning that the pole is 78 mi (13 ranges multiplied by 6 mi per range) west of the Willamette Meridian. This combination of township and range occurs in Oregon only in the western part of the town of Coos Bay.

In the bottom row, the first set of two numbers, 17, tells the section within the township where the pole is located. The second set of two numbers, 20, gives the PP&L grid number. Units in the grid are numbered both horizontally and vertically from 0 through 9, beginning in the bottom left-hand corner. The first number in the second set of numbers indicates the horizontal side of the grid; the second number gives the vertical side. Grid number 20 means the third square to the right of the starting point in the 0 (bottom) row. The final two digits, 02, show the actual pole number within the grid.

On a foggy morning, after locating an important outcrop next to a PP&L pole with no landmarks in sight, how can you use this system to find yourself on a map?

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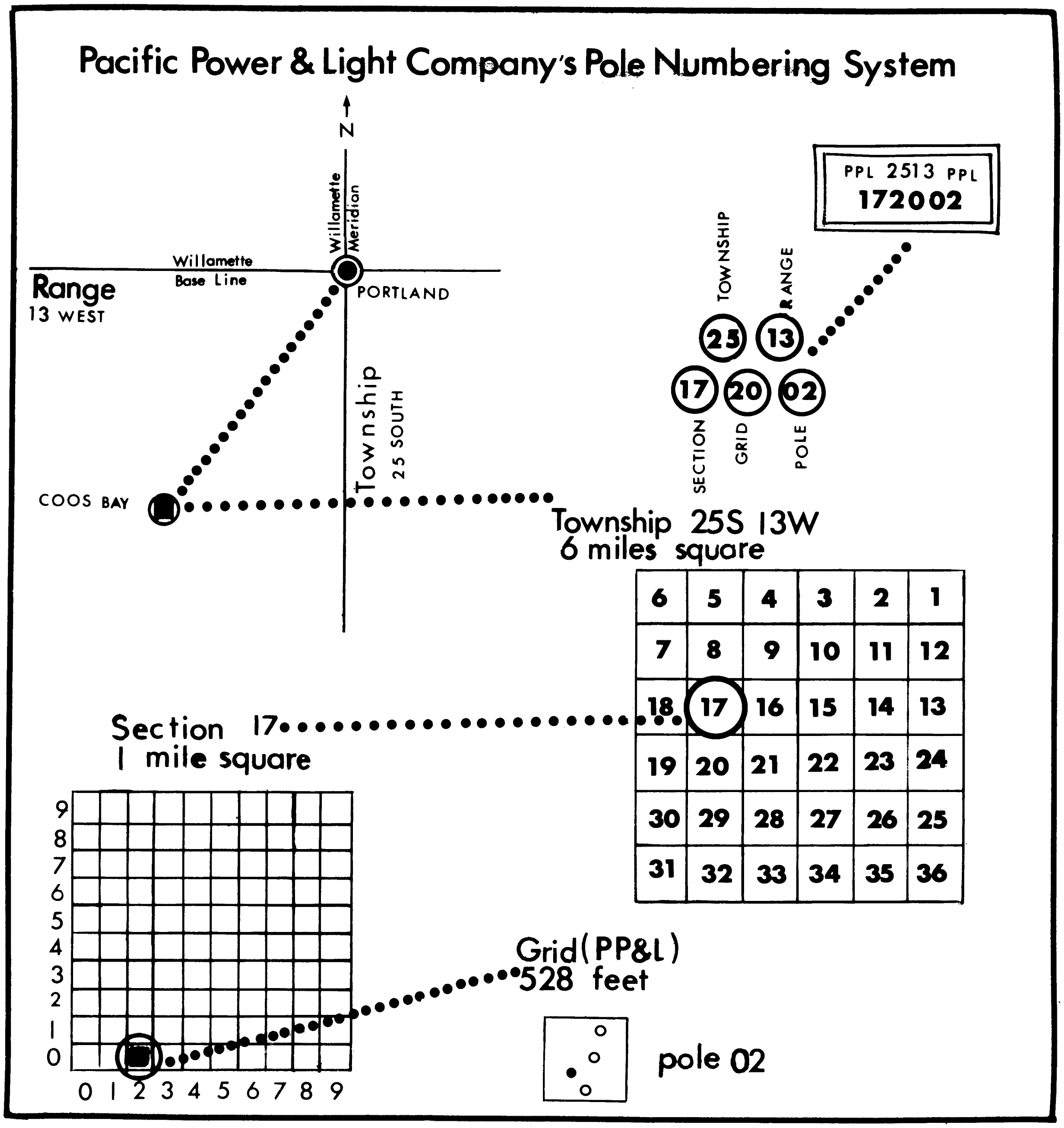
*Source: Pacific Power and Light Company, 920 S.W. 6th, Portland, Oregon 97204. For more information write or call Leonard Bacon, (503) 243-4763.



First, you should know if you are east or west of the Willamette Meridian and north or south of the Willamette Base Line. Note the township, range, and section numbers on the pole, then locate yourself on an appropriately marked county, U.S. Geological Survey, or U.S. Forest Service map. Once you have identified the section you are in, divide it with 10 horizontal and 10 vertical lines into 100 equal squares. Then, after you have determined which square in the PP&L grid you are in, you have located yourself in a block that is 580 ft on a side.

If you are ever lost but are fortunate enough to be near a PP&L power pole, walk down the line of poles and watch the numbers change. Within a few poles, the grid number will change, thereby giving the direction. For example, if grid number 20 changes to 21, you are walking north, because 21 is the number of the next square north of 20. If the grid number changes to 30, you are headed east; 10, west. Moving south, however, you will see the entire bottom line of numbers change, because the section number will also change. The pole number will now show section 20, grid number 29, and the individual pole number within the grid.

The one exception to this pole numbering system in the six-state PP&L service area is the former California-Oregon Power Company (COPCO) area of southwest Oregon. COPCO's system of numbering poles is still in use in that area, which extends from the Roseburg-Sutherlin area to Yreka, California, and west from Klamath Falls to the Pacific coast.

Some confusion can also arise if you are close to the Willamette Meridian or Willamette Base Line. The pole numbers will not tell you if you are east or west of the meridian or north or south of the base line. But given time and a map, a good geologist or an experienced outdoorsperson should be able to determine that. □

A petrified walnut preserved along with a small stem and a leaf in a specimen from the Clarno Formation. This photograph by Thomas J. Bones is on the cover of the Atlas of Fossil Fruits and Seeds from North Central Oregon.

Book review

by Ralph S. Mason, former State Geologist

ATLAS OF FOSSIL FRUITS AND SEEDS FROM NORTH CENTRAL OREGON, by Thomas J. Bones, OMSI Occasional Papers in Natural Science, No. 1, 1979, 23 p., plates. A compilation of 39 genera of Eocene age fruit and seed specimens collected in the world-famous Clarno Nut Beds. The specimens are distributed through 23 families, many of which are now extinct, with others related to plants now living in the forests of southern Asia.

Specimens of the fruits and seeds, many of them visible only with the aid of a hand lens, were collected since 1943 by Thomas Bones, a layman, now living in Vancouver, Washington. Large quantities of his collected material are now in the National Museum of Natural History, Smithsonian Institution, Washington, D.C. A permanent display is also housed at the Cant Ranch Visitors Center in the John Day Fossil Beds National Monument near Dayville, Oregon.

Identification of the Clarno flora is an ongoing project with R.A. Scott of the U.S. Geological Survey, assisted by Elso Barghoorn of Harvard and Marjorie Chandler of the British Museum. The *Atlas* contains 69 pictures of the fruits and seeds, but no detailed descriptions are included. The specimens, unlike so much fossil material collected elsewhere, are largely undeformed and appear in the round. Many specimens have been silicified, and nuts with opalized meats are not uncommon.

The Clarno flora provides an insight into the tropical and sub-tropical climate, the volcanic activity, and the physical conditions that existed in north central Oregon during late Eocene time. □

Columbia County No. 1 well records for 1977 to be released

The Department will release 1977 well records of the Reichhold Energy Columbia County No. 1 gas exploration hole on September 5, 1979.

The hole was drilled in 1977 in the NW¼ sec. 11, T. 6 N., R. 5 W., Columbia County. Redrilling in 1979 resulted in the discovery of the Mist gas field.

Oregon statute requires that all records remain confidential for 2 years after abandonment or completion of a well. Records of the redrilling will not, therefore, be released until 1981.

Records of the original drilling include: well history, litholog, dip log calculations, induction electric log, acoustic velocity log, and well samples (cuttings).

When facilities have been arranged, the samples will be displayed for inspection. Meanwhile, anyone wanting to see them should call Vern Newton, (503) 229-5580.

Copies of the logs can be examined at the Department's Portland, Baker and Grants Pass offices after 9 a.m., September 5. Companies selling the information are: Munger Oilgram, P.O. Box 45738, Los Angeles, California 90045, phone: (213) 776-3990; M.J. Systems, P.O. Box 9098, Bakersfield, California 93309, phone: (800) 525-5951; Petro-Well Libraries, Inc., 150 Security Life Building, 1616 Glenarm Place, Denver, Colorado 80202, phone: (303) 892-5513; Rocky Mountain Well Log Service, 1375 Delaware Street, Denver, Colorado 80204, phone: (303) 825-2181; and Petroleum Information Log Services, P.O. Box 9279, 4300 Easton Drive, Bakersfield, California 93389, phone: (805) 327-5393.

The following table summarizes all the drilling done by Reichhold and partners in Oregon.

Summary of Reichhold Drilling in Oregon

Permit Number	Company	Well Name	Location	Total Depth (ft)	Status
65	Reichhold	NNG-Crown Zellerbach No. 1	NE¼ sec. 22, T. 2 S., R. 10 W. Tillamook Co.	5557	Abandoned August 1975
66	Reichhold	NNG-Finn No. 1	SW¼ sec. 17, T. 6 S., R. 4 W. Polk Co.	7258	Abandoned October 1975
67	Reichhold	NNG-Merrill No. 1	SW¼ sec. 24, T. 8 S., R. 4 W. Marion Co.	5282	Abandoned October 1975
68	Reichhold	Crown Zellerbach No. 2	NW¼ sec. 8, T. 4 N., R. 3 W. Columbia Co.	5805	Abandoned November 1975
69	Reichhold	Columbia County No. 1	NW¼ sec. 11, T. 6 N., R 5 W. Columbia Co.	3111	Suspended September 29, 1977
69RD	Reichhold	Columbia County No. 1	NW¼ sec. 11, T. 6 N., R. 5 W. Columbia Co.	3105	Completed May 1979; 1690 MCF/D
71	Reichhold	Dia-Shamrock Columbia County No. 2	NE¼ sec. 14, T. 6 N., R. 5 W. Columbia Co.	2780	Abandoned July 1978
72	Reichhold	Dia-Shamrock Columbia County No. 3	NE¼ sec. 10, T. 6 N., R. 5 W. Columbia Co.	2932; redrilled to 2993	Completed June 1979; 4000 MCF/D
73	Reichhold	Dia-Shamrock Longview-Fibre No. 1	SW¼ sec. 11, T. 6 N., R. 5 W. Columbia Co.	3088	Abandoned October 1977
86	Reichhold	Columbia County No. 4	NE¼ sec. 15, T. 6 N., R. 5 W. Columbia Co.	2936	Completed May 1979 900 MCF/D
87	Reichhold	Columbia County No. 5	NW¼ sec. 10, T. 6 N., R. 5 W. Columbia Co.	3116	Abandoned July 1979
88	Reichhold	Grimsbo No. 1	SE¼ sec. 9, T. 6 N., R. 5 W. Columbia Co.		Location ready
89	Reichhold	Libel No. 1	NW¼ sec. 15, T. 6 N., R. 5 W. Columbia Co.		Location ready
91	Reichhold	Columbia County No. 6	SW¼ sec. 10, T. 6 N., R. 5 W. Columbia Co.		Drilling
92	Reichhold	Columbia County No. 7	SE¼ sec. 4, T. 6 N., R. 5 W. Columbia Co.		Location ready

New Oregon heat flow publication available

Special Paper 4, *Heat Flow of Oregon,* by D.D. Blackwell, D.A. Hull, R.G. Bowen, and J.L. Steele, is now available at the Oregon Department of Geology and Mineral Industries. This 42-page book, with map, describes the results of an 8-year project to investigate the geothermal features of Oregon. The abstract from the paper is printed below.

ABSTRACT

An extensive new heat flow and geothermal gradient data set for the State of Oregon is presented on a contour map of heat flow at a scale of 1:1,000,000 and is summarized in several figures and tables. The 1:1,000,000 scale heat flow map is contoured at 20 mW/m^2 (0.5 HFU) intervals. Also presented are maps of heat flow and temperature at a depth of 1 km averaged for $1° \times 1°$ intervals. Histograms and averages of geothermal gradient and heat flow for the State of Oregon and for the various physiographic provinces within Oregon are also included.

The unweighted mean flow for Oregon is 81.3 ± 2.7 mW/m^2 (1.94 ± 0.06 HFU). The average unweighted geothermal gradient is 65.3 ± 2.5 °C/km. The average heat flow value weighted on the basis of geographic area is 68 ± 5 mW/m^2 (1.63 ± 0.12 HFU), and the average weighted geothermal gradient is 55.0 ± 5 °C/km.

On the basis of the data, the State of Oregon can be divided into 4 heat flow provinces. The first of the heat flow provinces occupies the western third of the state and includes the Coast Range, Willamette Valley, Klamath Mountains, and Western Cascade Range provinces. The mean heat flow for these provinces is 41.8 ± 1.3 mW/m^2 (1.00 ± 0.03 HFU), and the average gradient is 26.4 ± 1.0 °C/km. Heat flow values within these provinces are relatively uniform, but low, with no evidence of extensive convective heat transfer.

The second group of provinces includes the Deschutes-Umatilla (Columbia) Plateau and Blue Mountains provinces in the northeastern third of the state. The mean heat flow for these two provinces is 65.2 ± 2.6 mW/m^2 (1.56 ± 0.06 HFU), and the average gradient is 43.7 ± 2.5 °C/km. This heat flow is considered anomalously high as the crust contributes very little to the surface heat flow and mantle heat flow value is 50-55 mW/m^2 (1.2-1.3 HFU). There is ubiquitous water motion along flow contacts in the Columbia River Basalt. However, the water motion appears to be relatively slow and has only a minor effect on the measured heat flow values.

The third group of provinces occupies the southeastern third of the state and includes the High Lava Plains, Basin and Range, Owyhee Upland, and Western Snake River Basin provinces. The mean heat flow is 98.4 ± 3.8 mW/m^2 (2.34 ± 0.08 HFU), and the mean gradient is 89.1 ± 3.4 °C/km. The heat flow and geothermal gradient are extremely high and are related to the extensive volcanism and tectonism characteristic of these provinces within the past 15-20 m.y. Disruption of conductive heat transport both by regional ground water systems and by hydrothermal convection systems is common, resulting in large scatter in the observed heat flow values. Large scale crustal effects on the heat flow are also observed. Because of the high geothermal gradient and high heat flow, this area of the state probably has the greatest potential for geothermal development for both high and moderate temperature geothermal systems.

The fourth area of the state includes the High Cascades Range. Reliable heat flow data are not available for the central and eastern parts of this area of extensive young volcanism; however, heat flow values along the northwestern boundary average 105.1 ± 8.5 mW/m^2 (2.51 ± 0.20 HFU) and the geothermal gradient averages 61.3 ± 3.4 °C/km. More data are needed for the High Cascade Range in order to properly evaluate its heat flow and geothermal potential. However, based on the heat flow data along the northwestern boundary, the young volcanism, and the existence of many hot springs along the western boundary, the geothermal potential of this province is undoubtedly large.

Thus, the overall heat flow pattern in the state consists of subnormal heat flow values in the western one-third of the state separated by the High Cascade Range from slightly high to very high heat flow values in the eastern two-thirds of the state. The pattern is related to the effect of Cenozoic plate tectonic activity in the Pacific Northwest and to subduction of the Juan de Fuca plate beneath the Pacific Northwest during the past few tens of millions of years.

The complete report, with map, costs \$3.00. Address orders to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201. Include payment if your order is for less than \$20.00. □

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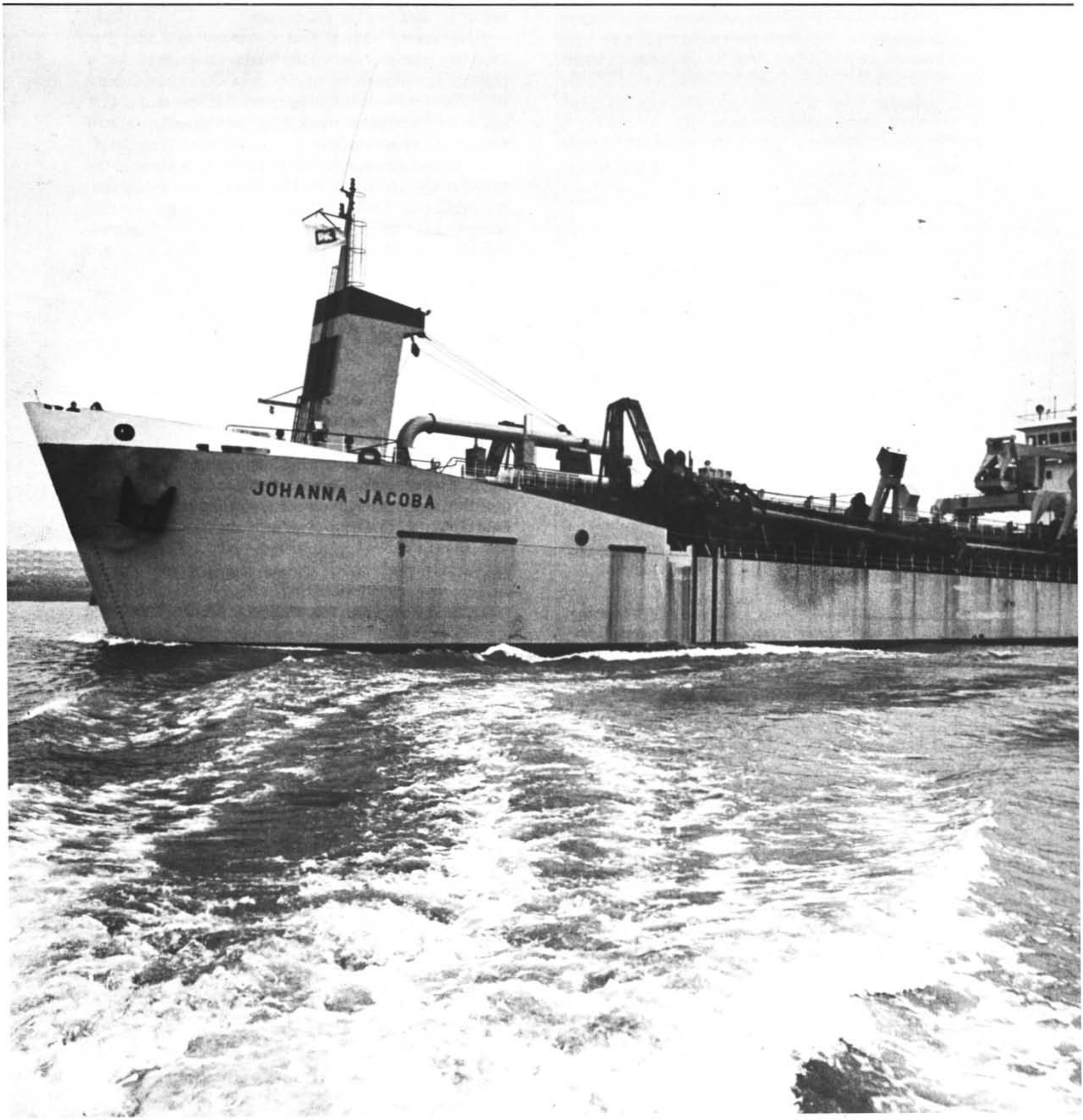

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COVER PHOTO

A modern trailing suction hopper dredge with suction pipe and draghead stowed for cruising. This vessel has speed of 12.8 knots, length of 104 m, hopper capacity of 3,250 m^3, and dredging depth of 35 m. (Photo courtesy IHC Holland Corporation)

Fourth Mist gas well largest yet

Reichhold Energy Corporation, Tacoma, Washington, and its partners, Diamond Shamrock Corporation and Northwest Natural Gas Company, hit the biggest of its four producing natural gas wells near Mist on August 14, 1979. This well has turned out to be the largest, with a flow rate that by itself surpasses the output of all three earlier discoveries.

Northwest Natural Gas Company said that "as soon as possible" it would begin final plans for a pipeline to connect the gas fields in Columbia County with the utility's distribution system. It also said that it had asked for eight more drilling permits to continue to explore the area this fall.

The companies involved in the exploration said the fourth well—identified as REC-Columbia County No. 6, Redrill No. 2—had a flow rate of 6.5 million cubic feet per day. Earlier wells showed flow rates of approximately 1.6 million, 865,000, and 3.75 million cubic feet per day respectively.

Participation by Columbia County in the exploration is by Northwest Natural Gas, through a wholly owned subsidiary, Oregon Natural Gas Development Corporation.

Northwest Natural Gas said the fourth well is in a separate fault block and indicates there is another gas pool in the area. The company said more drilling would be needed to determine its size.

The utility said it has completed preliminary engineering studies in preparation for right-of-way acquisition and construction for a pipeline from the Mist field to its North Coast pipeline, near Clatskanie. □

CONTENTS

Offshore sand and gravel resources of the Pacific Northwest

by George W. Moore and Michael D. Luken, U.S. Geological Survey, Menlo Park, California 94025

ABSTRACT

The Oregon and Washington continental shelf contains an estimated eight billion m³ of gravel, the potentially most valuable hard-mineral resource of the shelf. At the present rate of consumption in Oregon and Washington, the gravel on the outer continental shelf to a water depth of 100 m would last about 200 years. Modern dredging vessels, if permitted, may soon be able to deliver clean aggregate to discharge points at Portland and Seattle at a profit, as is now being done by the marine sand and gravel industries in the North Sea and off Japan.

Environmental factors will mainly determine whether such operations begin. Only a small fraction of the offshore gravel lies in water shallower than 20 m, where coastal erosion and herring spawning grounds may present environmental restrictions. The rounded, 0.2-m-deep tracks left by suction dredges do not interfere with trawling nets, and, during a 6-month study in the English Channel, larva of fish-food organisms from the plankton rapidly recolonized a dredge test area. Biologic studies near clay discharges from an English ceramics plant show that open-sea fish are tolerant of suspended sediment, perhaps because storms also stir it up. The eggs of sole, rockfish, crab, and shrimp, the principal bottom species harvested on the outer continental shelf of the Pacific Northwest, mature near the water surface, where they would probably be little affected by the mining. More research is needed, however, to verify fully the compatibility between a local marine gravel industry and the fishing industry.

INTRODUCTION

Quarry operators in the United States mine enormous volumes of sand and gravel for construction, road bases, and fill. The industry produces about 3 m³ per year for each citizen (Evans, 1978). Oregon and Washington are endowed with large resources of sand and gravel, but because of a high transportation cost on land, the deposits adjacent to population centers are being depleted rapidly (Hines, 1969; Zimmerman and Moen, 1966). Also, some deposits near the cities have been removed from production because the land has become more valuable for other purposes. This situation is aggravated further by environmental factors — many of the remaining deposits lie where incompatible land uses impinge against them, where disposal of processing water is difficult, and where truck traffic generates complaints. Consequently, resources farther from urban areas are becoming more valuable. This paper assesses the resources of sand and gravel on the continental shelf off Washington and Oregon and evaluates the factors affecting their possible future utilization.

In the United Kingdom, Japan, and the Netherlands, a similar pressure caused by population growth and the consequent need for resources has created a gravel-dredging industry on the continental shelf (Baram and others, 1978). Initially, small dredges were used at nearshore sites, but the industry has now evolved to the extent that in the North Sea some vessels that process gravel from the sea floor have capacities as large as 9,000 m³, and a single dredge may alternate deliveries between London and continental Europe as the demand dictates.

Off the United Kingdom, dredging for sand and gravel is permitted only on the outer part of the continental shelf, where dredge-generated bottom disturbances and water-turbidity affect the fish and shellfish industries less, and where the sediment removal does not cause coastal erosion.

Operations where heavy seas are common require large ocean-going self-contained hopper dredges (Figure 1) (Hess, 1971). These vessels combine a ship's hull with dredging machinery and with holds for collecting and transporting the products. The most common type of dredge is the trailing suction dredge, in which a pump at the ship draws up a slurry of gravel and water from the sea floor while the vessel moves slowly forward.

In the North Sea, suction dredges routinely take gravel from depths as great as 50 m. A pump in the ship's hull lifts the gravel through steel trailing pipes, and in some cases jets at the draghead on the sea floor assist. Friction in the trailing pipes limits the working depth of nonassisted suction dredges, and the pipes need to be rigid so that the suction will not collapse them. A few new dredges, with pumps on the pipe at depth rather than at the ship, are now operating at a depth of 80 m (Koster, 1979). They can use flexible pipes above the pump, because collapse is not a problem.

On each pass over an area, a trailing suction dredge processes a sea floor layer about 0.2 m thick. It changes

Figure 1. British sand and gravel dredger Cambrook, *built in 1967, has capacity of well over 2,000 tons. (Photo from Hess, 1971)*

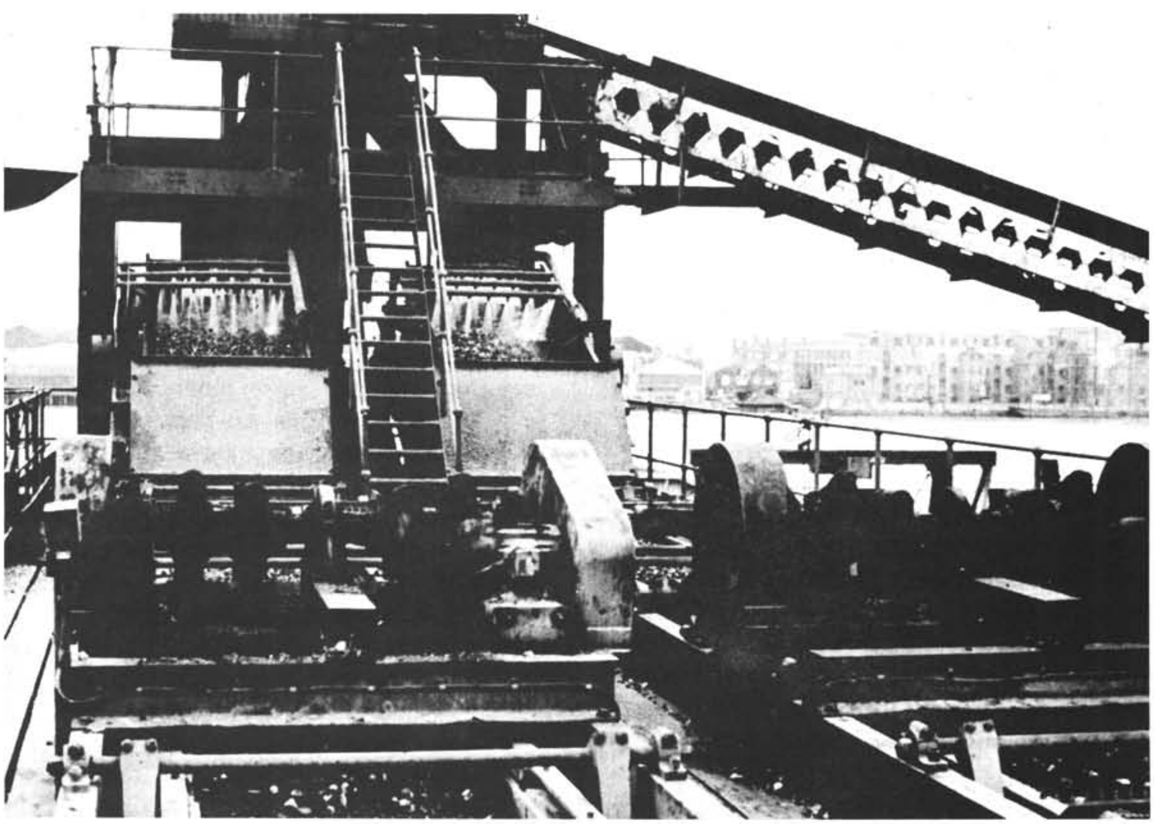
the sea-floor topography very little, a factor that is important where fish trawlers also use the area. Dredges can economically work areas where the gravel is less than 1 m thick, and they can mine thicker areas by repeated passes.

To meet the requirements of operating in the open sea, the European marine sand and gravel industry has developed hopper dredges that can carry a large and valuable load for many hours of running time to distant markets. This evolution of the equipment also assures a profitable traverse up the River Thames to London, a long inland run similar to those at Portland and Seattle.

The process of lifting and loading the sand and gravel removes most of its intermixed silt and clay, and vessels that screen the product at sea have been tried in Europe. At many onshore processing plants, disposal of the fines and waste water has become expensive and environmentally difficult. When unneeded fractions are washed out and discharged at sea, payloads are increased and operations at the unloading stations are simplified.

Self-contained hopper dredges designed for mining, processing, and transporting sand and gravel can serve a group of widely separated docks, each situated near a local market. Scraper buckets and belt conveyors unload clean gravel onto dockside conveyors (Figure 2). Drained marine aggregate usually can be used directly for concrete without extracting the remaining salt.

Figure 2. Dockside sand and gravel treatment plant in the London area. (Photo from Hess, 1971)



Where specifications do call for the salt to be flushed out, any remaining silt and clay that are removed with it can be caught in settling tanks to avoid harbor pollution.

New York, Boston, and Los Angeles are likely to lead the way for offshore sand and gravel mining in the United States. Oregon and Washington now dredge navigational channels to keep them open, and offshore mining in the Pacific Northwest will probably first be permitted for use at coastal sites. As urban aggregate supplies shrink, a need to maximize onshore and offshore environmental safeguards will probably govern the future dredging of marine sand and gravel for construction.

DISTRIBUTION OF OFFSHORE SAND, GRAVEL, AND SHELL DEPOSITS

Two main types of data sources supplied the seafloor information for this paper. Bottom-character notations came from the 20 U.S. National Ocean Survey Charts in the series 18480 to 18602 that cover this coast, and sediment analyses came from cores and grab samples collected by Oregon State University and the University of Washington (Burnett, 1968; Chambers, 1968; Runge, 1966). Where these two sources of data overlap, the agreement between them is excellent.

Figure 3 shows the distribution of sediment types and rock outcrops on the continental shelf off Oregon and Washington. Figure 4 is a genetic summary diagram illustrating the geography of the northern part of the shelf area at the time when the coarser deposits were laid down.

ORIGIN OF THE DEPOSITS

Present-day bottom currents on the outer continental shelf off Oregon and Washington are too weak to redistribute gravel extensively. The gravel beds are relict, dating from about 15,000 years ago during the Pleistocene Epoch. Sea level was then about 200 m lower than it is now, and the continental shelf was exposed because ice sheets on the continents incorporated an enormous volume of water that has since been returned to the oceans.

Two main types of processes formed the gravel bodies. In the north, vigorous meltwater streams flowed across the exposed continental shelf from former glaciers in Washington and British Columbia and laid down broad fans of gravel beyond the positions of the ice fronts (Figure 4). In the south, off Oregon, Pleistocene waves reworked gravel from stream deposits and eroded rock from former headlands and shelf platforms to produce smaller gravel bodies, most of which lie near submarine rock outcrops.

Nearly all of Canada was covered by the continental ice sheet. The ice margin reached to the edge of the continental shelf off British Columbia, impinged against the north flank of the Olympic Mountains, and extended southward as a long lobe in the Puget lowland east of the mountains (Prest, 1969). Wells drilled for oil off southern British Columbia show that the glacial deposits on the shelf are 60 to 160 m thick (Shouldice, 1971, Figure 17). The gravel beds seaward of the mouth of the Strait of Juan de Fuca are most extensive on banks at a water depth of 170 m, near the depth to which sea level was lowered during the Pleistocene. Subsequent marine deposition has not covered the well-sorted gravel on the sea floor.

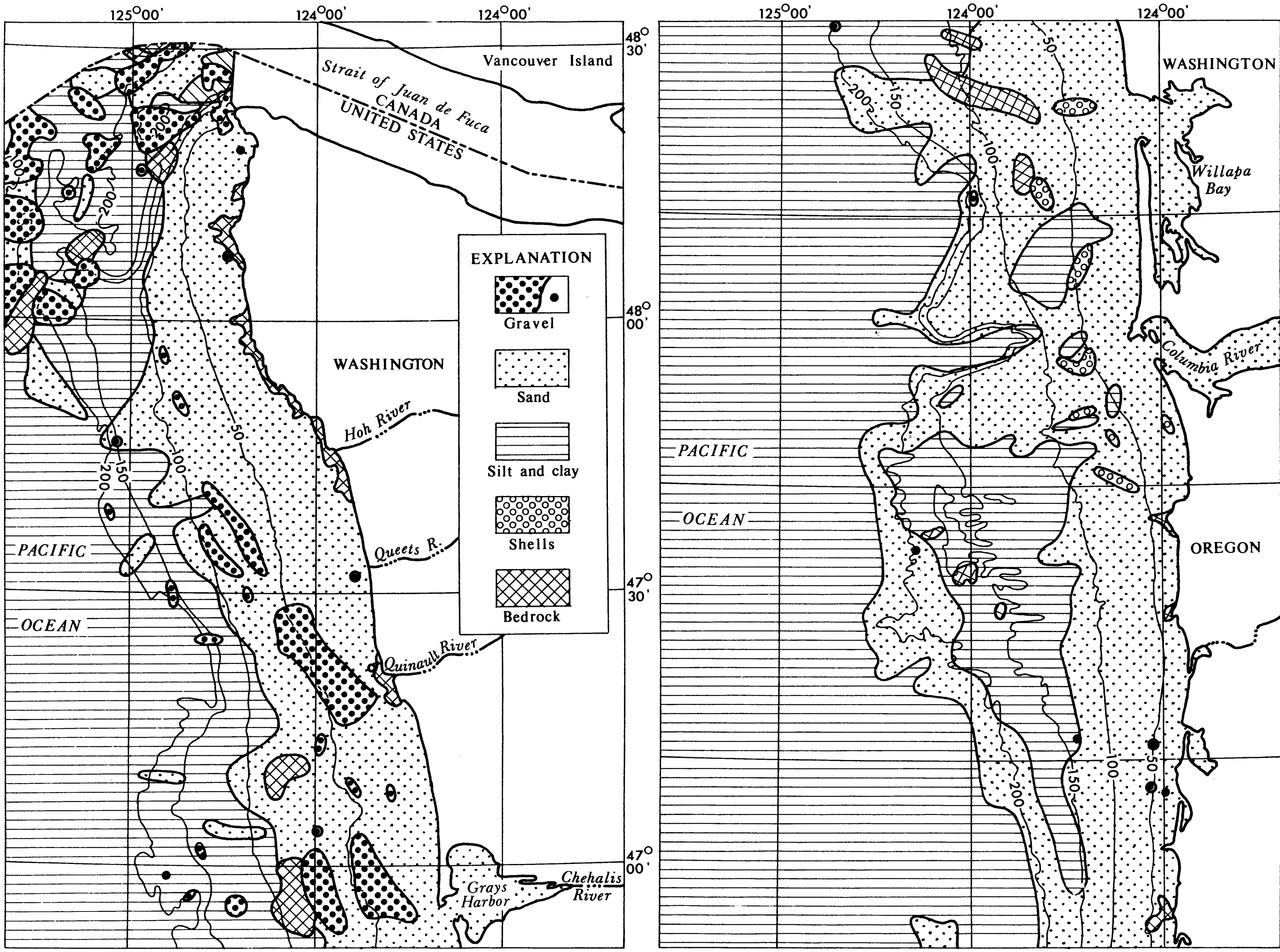
The composition of a gravel bed off Grays Harbor, Washington, gives a clue as to its source. Venkatarathnam and McManus (1973) report that the pebbles in this deposit are 69 percent andesite, a rock uncommon in the nearby Coast Range but the predominant rock of the volcanoes of the Cascade Range, 200 km farther inland. During the Pleistocene, meltwater from the Puget glacial lobe and from glaciers at Mount Rainier carried the andesite pebbles and other glacially derived Cascade Range rocks down the valley of the Chehalis River and out onto the continental shelf at Grays Harbor. There, the river laid down the nonindigenous clasts on a terrain where the bed rock is almost totally dissimilar.

Gravel on the continental shelf off the Olympic Mountains farther north contains almost no andesite and probably originated as outwash from valley glaciers flowing down from the nearby Olympic Mountains, which contain little andesite (Tabor and Cady, 1978).

Kulm and others (1975) used distinctive minerals on the continental shelf as natural tracers of transport paths to show that present-day, long-wavelength winter waves stir the bottom and keep fine river sediment moving across the shelf to submarine canyons and the continental slope. This process prevents the gravel beds from being covered by silt and fine sand.

Several of the larger gravel bodies off Oregon lie in swales between submarine banks. During the postglacial rise of sea level, the surf concentrated the gravel clasts in pocket beaches that filled former shoreline reentrants on what is now the continental shelf. Such wave action improved the quality of the gravel aggregate by breaking down and removing soft sedimentary and metamorphic pebbles.

Relict shell beds lie near many submarine rock outcrops, and former surf probably concentrated the shells in the same way as it did the gravel. An even larger group of shell beds arcs around the mouth of the Columbia River at an average depth of 70 m. The exposure of these old surf-sorted shells on the sea floor verifies that the bulk of the suspended load from the


125°00'
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Vancouver Island
Strait of Juan de Fuca
CANADA
UNITED STATES
WASHINGTON
Hoh River
Queets R.
Quinault River
Grays Harbor
Chehalis River
PACIFIC
OCEAN
EXPLANATION
Gravel
Sand
Silt and clay
Shells
Bedrock
200
150
100
50
125°00'
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WASHINGTON
Willapa Bay
46° 30'
Columbia River
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OREGON
45° 30'
PACIFIC
OCEAN

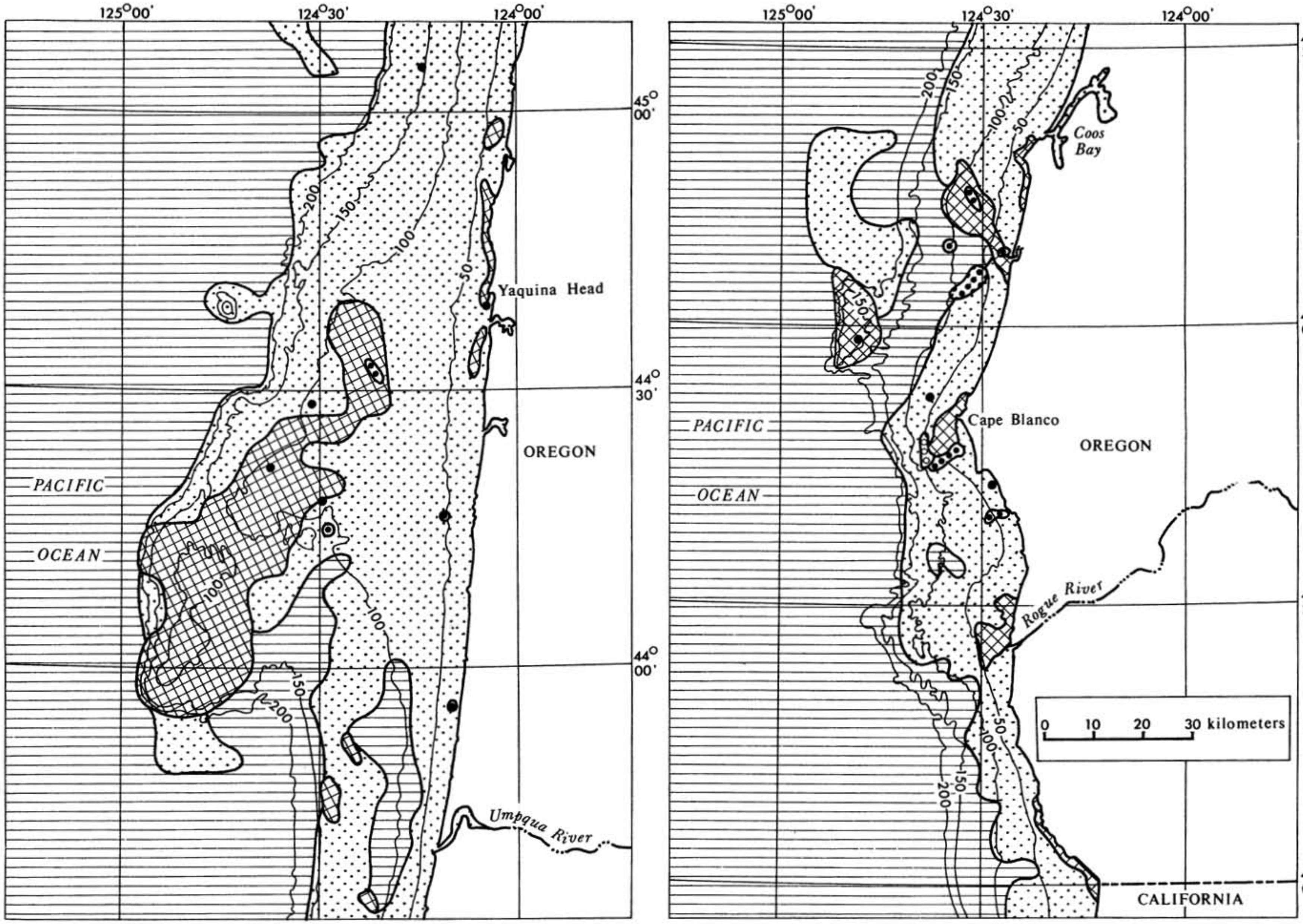

Figure 3. Sea floor materials off the coast of Washington and Oregon. Submarine contours in meters.

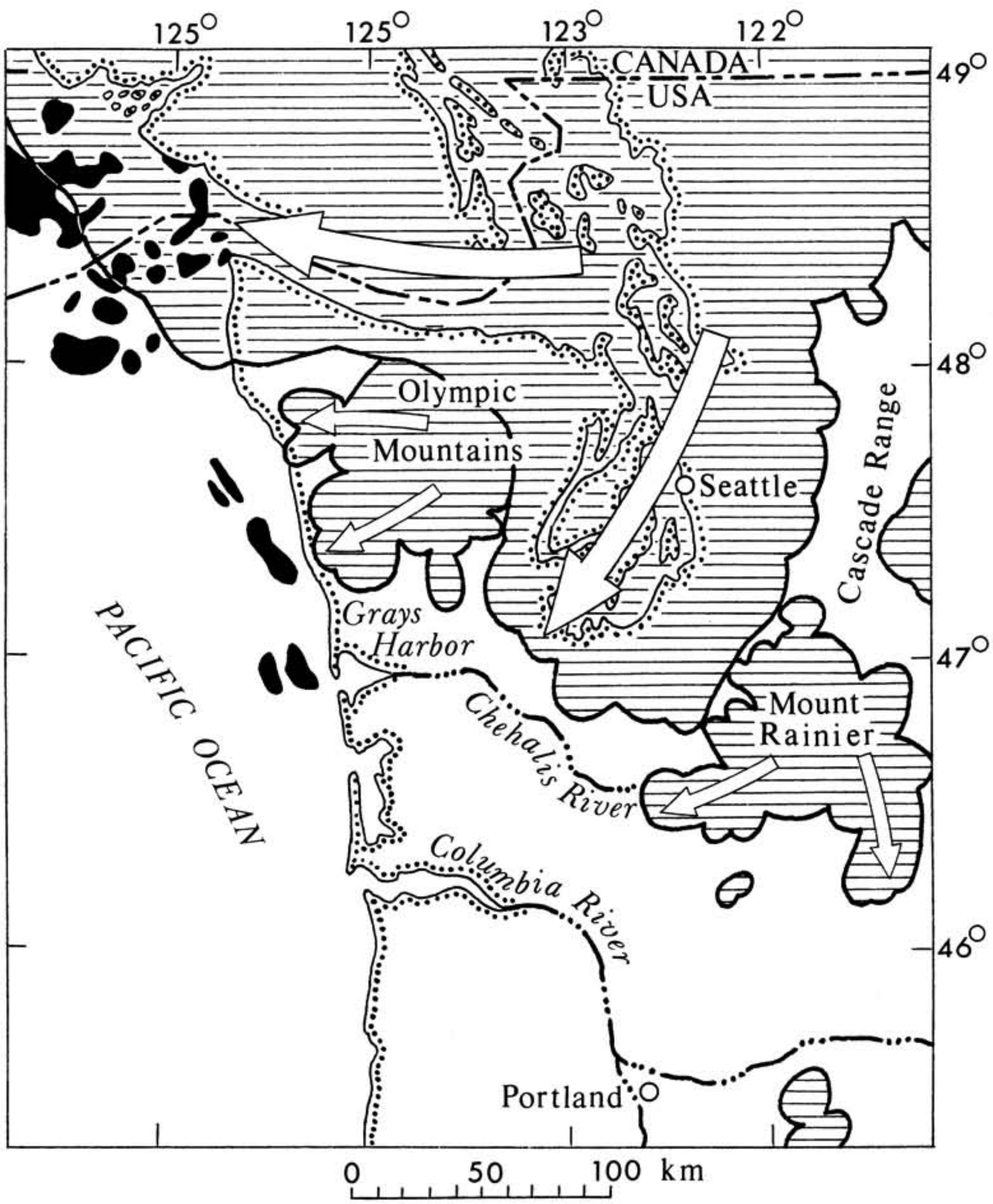

Figure 4. Spatial relations between gravel deposits on the continental shelf (black areas) and the extent of former glacial ice (ruled). Smaller arrows indicate the flow directions of ice in mountain glaciers; larger arrows the directions in the continental ice sheet (Prest, 1969).

Columbia bypasses the continental shelf, for otherwise they would be covered by sediment. Between sea-floor bedrock outcrops 20 km north and south of the mouth of the river, the continental shelf has an area of about 1,900 km^2. If the annual sediment load of the Columbia River of 12 million m^3 (Kulm and others, 1975) had been deposited within this area since sea level reached its present height about 5,500 years ago, river sediment would now bury the relict shells to a depth of 35 m.

RESOURCES

Although fairly good information is available on the thickness of the Pleistocene deposits as a whole (Snavely and others, 1977), we do not now have good information on the thickness of the individual sea-floor layers that have been mapped. Because at least several data points define the larger deposits, we tentatively hypothesize that they are at least 1 m thick. At onshore

Table 1. Offshore gravel deposits of Washington and Oregon

Center of deposit		Area (square kilometers)	Volume (million cubic meters)		Average water depth (meters)
N lat	W long		1-meter thickness	5-meter thickness	
48°28'	124°56'	58	58	290	150
48°27'	124°47'	22	22	110	280
48°24'	125°08'	32	32	160	170
48°23'	124°46'	24	24	120	70
48°21'	124°55'	85	85	425	200
48°19'	125°20'	128	128	640	140
48°19'	125°05'	36	36	180	170
48°19'	124°42'	1	1	5	20
48°17'	125°58'	4	4	20	210
48°14'	125°10'	5	5	25	210
48°14'	125°31'	13	13	65	160
48°11'	125°19'	94	94	470	170
48°07'	125°44'	2	2	10	20
48°05'	125°07'	23	23	115	170
48°03'	125°27'	313	313	1565	170
48°01'	125°13'	47	47	235	170
47°56'	124°55'	5	5	25	90
47°51'	124°52'	8	8	40	90
47°47'	125°02'	2	2	10	170
47°39'	125°03'	5	5	25	170
47°37'	124°42'	59	59	295	70
47°34'	124°46'	37	37	185	90
47°32'	124°24'	2	2	10	20
47°30'	124°41'	4	4	20	80
47°30'	124°53'	9	9	45	170
47°25'	124°47'	8	8	40	170
47°22'	124°21'	1	1	5	20
47°22'	124°28'	209	209	1045	40
47°14'	124°28'	7	7	35	60
47°09'	124°24'	8	8	40	50
47°08'	124°18'	5	5	25	30
47°04'	124°30'	2	2	10	70
47°02'	124°48'	4	4	20	140
46°59'	124°54'	1	1	5	160
46°57'	124°50'	3	3	15	170
46°57'	124°29'	90	90	450	70
46°57'	124°20'	127	127	635	40
46°56'	124°43'	16	16	80	130
46°51'	124°52'	2	2	10	200
46°32'	124°30'	4	4	20	170
45°53'	124°38'	1	1	5	190
45°32'	124°13'	1	1	5	130
45°32'	124°02'	2	2	10	50
45°27'	124°02'	2	2	10	50
45°27'	124°00'	1	1	5	30
45°05'	124°14'	1	1	5	150
44°39'	124°05'	1	1	5	10
44°32'	124°22'	9	9	45	60
44°29'	124°31'	1	1	5	90
44°22'	124°38'	1	1	5	90
44°18'	124°30'	1	1	5	90
44°16'	124°12'	2	2	10	50
44°15'	124°29'	6	6	30	100
43°56'	124°10'	3	3	15	20
43°14'	124°32'	8	8	40	70
43°09'	124°35'	5	5	25	90
43°08'	124°27'	3	3	15	20
43°06'	124°30'	9	9	45	60
43°04'	124°32'	20	20	100	70
42°58'	124°48'	1	1	5	170
42°52'	124°38'	1	1	5	70
42°46'	124°35'	15	15	75	40
42°43'	124°29'	1	1	5	10
42°40'	124°28'	5	5	25	40

outcrops, prisms of beach sediment and layers of outwash gravel are typically 5 m thick. Therefore, the resources of gravel are quoted on the basis of assumed thicknesses of 1 and 5 m (Table 1).

Assuming the 5-m thickness, the total resource of gravel without overburden of finer material on the Oregon and Washington continental shelf is 8.0 billion m^3. That on the outer continental shelf to a depth of 100 m is 3.3 billion m^3. At the present rate of consumption in Oregon and Washington, this supply would last about 200 years.

FACTORS AFFECTING UTILIZATION

Dredges will begin to mine sand and gravel off the coasts of Oregon and Washington when the demand is high enough and when society judges the environmental safeguards to be adequate.

As Oregon's supply of onshore sand and gravel has declined, crushed basalt has partly replaced gravel in construction aggregate. For many uses, however, gravel with rounded water-worn pebbles is superior to crushed stone with angular clasts because the gravel mixes better in concrete and takes the shape of forms better.

The history of the aggregate industry in Japan (Baram and others, 1978) might parallel that of the Pacific Northwest. As urbanization depleted local supplies of sand and gravel in Japan, the construction industry placed a greater reliance on crushed stone. Then, as the demand for high-quality aggregate increased further, large-scale offshore mining of gravel began.

If the mining industry is to utilize sand and gravel resources from the outer continental shelf, it must protect the fishing industry. Even though the dredges move slowly and cover only small areas during any one year, they are certain to kill some individual animals, especially slow-moving ones. An even more important consideration, however, is that the mining operations must not be permitted to damage fish habitats.

Most of the species caught by the fishing industry disperse buoyant eggs into the water, where they presumably would be little affected by the mining. But herring lay their eggs on the bottom, usually at a depth of less than 20 m, so expert biologic advice must guide any dredging at these depths.

Among the bottom species off Oregon and Washington, the fishing industry now takes mainly sole, rockfish, crab, and shrimp (Pruter and Alverson, 1972). The boats catch some of these animals on substrates other than gravel — for example, they take shrimp from glauconite-bearing green mud near the outer edge of the continental shelf and crab mainly from sand bottoms. The larva of dungeness crab mature near the water surface, but one stage of the young of tanner crab prefers a gravel or rock bottom. They generally live at a depth of more than 400 m, however, which is deeper than dredging is likely to be undertaken.

During dredging, large fish often follow along to feed on sand fleas and worms that are uncovered by the disturbance at the draghead. Suction dredges only rarely capture fin fish, however, and present research suggests that silt and clay thrown into suspension in the open ocean by dredging is not toxic to them (Gustafson, 1972). For example, fish were found to be little affected by the discharge of a clay-slurry waste from a ceramics plant near Plymouth, England (Wilson and Connor, 1976).

Trailing suction dredges leave behind an undredged layer of gravel to avoid dilution of the commercial product by the substrate, and they also leave behind interspersed patches of virgin sea floor between the dredge tracks. These undredged patches may serve as centers of redispersal for invertebrate animals used as food by the fish. In a study of a wide dredged channel near Le Havre, France, biologic monitoring over a 6-month period showed that recolonization was rapid and that the most important source of recolonization of fish-food organisms was by the settling and development of larva from the plankton (Lee and others, 1977).

CONCLUSIONS

If marine sand and gravel dredging begins off Oregon and Washington, coastal construction and filling probably will utilize some of the first material that is produced. The gravel deposits that are likely to be exploited first are those off Washington adjacent to Grays Harbor and the southern Olympic Mountains. Where these deposits are more than 3 nautical miles from shore and shallower than a 50-m working depth for suction dredges, they have a combined area of 225 km^2. The deposits are about 200 km by water from Portland and 300 km from Seattle. This transport distance may be compared with a presently profitable 200-km run from North Sea dredging sites to London by the way of the River Thames.

Some aspects of offshore sand and gravel operations are more environmentally acceptable than onshore operations. Environmental pressures against the onshore operations and depletion of deposits near the cities will partly govern the future use of the offshore resources. Present evidence suggests that the dredging will have little harmful effect on the fish, crab, and shrimp species now being taken from the outer continental shelf and will not physically interfere with fish trawling. But silt and clay overflow must be conducted downward below the surface water layer that carries fish eggs and larva (Yagi and others, 1977). Also, because coastal marshes are nursery areas for commercially important fish, any filling in of such areas must be carefully monitored to ensure that it does not harm the fishing industry.

ACKNOWLEDGMENTS

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Oregon Surface Mining and Reclamation Law changed

The 1979 Oregon Legislative Assembly passed Senate Bill 712 amending the Oregon Surface Mining and Reclamation Law. The bill has been signed by the Governor and becomes effective October 4, 1979.

ORS Chapter 517.780 has been amended regarding the exemptions provided for city or county governments. The exemption provisions of the law remain unchanged, but the language has been clarified. The Department recommends that all cities and counties which have previously submitted ordinances for the Department's consideration review these ordinances in light of the changes contained in Senate Bill 712 and new model ordinances recommended by the Association of Oregon Counties.

The fees for mining operations provided in ORS 517.800 were also changed by Senate Bill 712. This change provides for a $30 per year increase in both the new application and the renewal fee. The new application fee after the effective date will be $295, and the annual renewal fee will be $195. New mining permit applications and October renewal applications will be accepted at the old rates of $265 and $165 respectively, if postmarked prior to October 4, 1979.

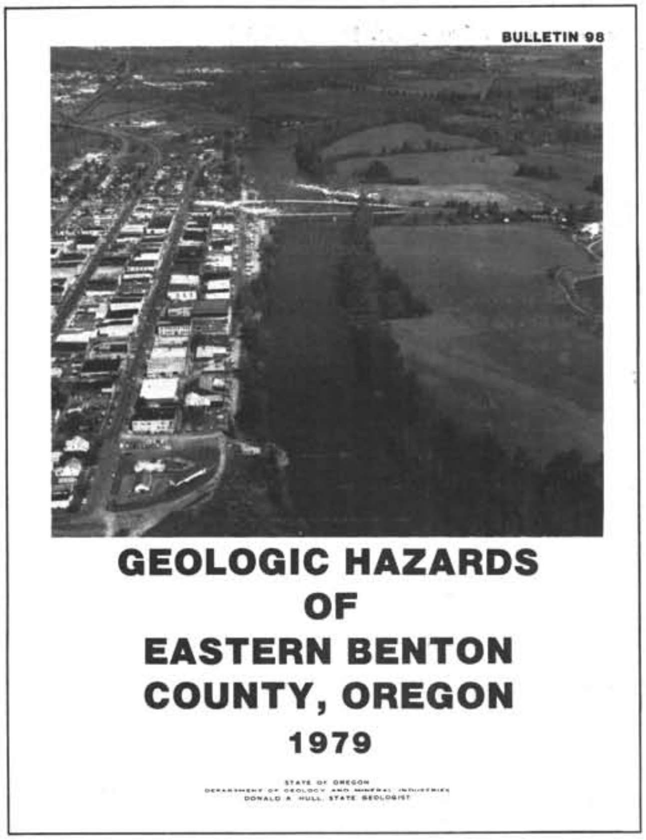
The changes in Senate Bill 712 will provide for more effective reclamation of Oregon mines and quarries and assist local governments in their mining activities. □

Applications for Oil and Gas Drilling Permits in Oregon

Permit number	Date issued	Company	Lease name and county	Location	Total depth (ft)
91	7-13-79	Reichhold Energy Corporation	Columbia County No. 6 (Columbia County)	SW¼ sec. 10, T. 6 N., R. 5 W.	3,466 2,956 RD-1 2,800 RD-2
92	7-13-79	Reichhold Energy Corporation	Columbia County No. 7 (Columbia County)	SE¼ sec. 4 T. 6 N., R. 5 W.	———
93	8-3-79	American Quasar Petroleum Co.	Longview Fibre Well No. 30-13 (Columbia County)	NW¼ SW¼ sec. 30 T. 6 N., R. 4 W.	———
94	8-3-79	American Quasar Petroleum Co.	Longview Fibre Well No. 25-33 (Columbia County)	NW¼ SE¼ sec. 25 T. 6 N., R. 5 W.	———
95	8-22-79	Reichhold Energy Corporation	Columbia County No. 8 (Columbia County)	SE¼ sec. 10 T. 6 N., R. 5 W.	———
96	8-22-79	Reichhold Energy Corporation	Libel No. 2 (Columbia County)	SE¼ sec. 15 T. 6 N., R. 5 W.	———
97	9-5-79	Floyd L. Cardinal	Watson Well No. 1 (Clatsop County)	NE¼ sec. 14 T. 7 N., R. 9 W.	———
98	9-11-79	Reichhold Energy Corporation	Columbia County No. 9 (Columbia County)	NW¼ sec. 1 T. 6 N., R. 5 W.	———
99	9-11-79	Reichhold Energy Corporation	Columbia County No. 10 (Columbia County)	SW¼ sec. 3 T. 6 N., R. 5 W.	———
100	9-11-79	Reichhold Energy Corporation	Columbia County No. 11 (Columbia County)	SE¼ sec. 11 T. 6 N., R. 5 W.	———

Applications for Oil and Gas Drilling Permits in Oregon (continued)

Permit number	Date issued	Company	Lease name and county	Location	Total depth (ft)
101	9-11-79	Reichhold Energy Corporation	Hammerberg No. 1 (Columbia County)	NE¼ sec. 14 T. 6 N., R. 5 W.	----
102	9-11-79	Reichhold Energy Corporation	Wall No. 1 (Columbia County)	SW¼ sec. 13 T. 6 N., R. 5 W.	----
103	9-11-79	Reichhold Energy Corporation	Busch No. 1 (Columbia County)	SW¼ sec. 15 T. 6 N., R. 5 W.	----
104	9-11-79	Reichhold Energy Corporation	Rawlinson No. 1 (Columbia County)	NW¼ sec. 13 T. 6 N., R. 5 W.	----
105	9-11-79	Reichhold Energy Corporation	Longview Fibre No. 2 (Columbia County)	SW¼ sec. 11 T. 6 N., R. 5 W.	----
106	9-12-79	American Quasar Petroleum Co.	Longview Fibre No. 31-24 (Columbia County)	SE¼ SW¼ sec. 31 T. 6 N., R. 4 W.	----
107	9-12-79	American Quasar Petroleum Co.	Longview Fibre No. 31-33 (Columbia County)	NW¼ SE¼ sec. 31 T. 6 N., R. 4 W.	----
108	9-12-79	American Quasar Petroleum Co.	Crown Zellerbach No. 15-14 (Columbia County)	SW¼ SW¼ sec. 15 T. 6 N., R. 4 W.	----
109	9-12-79	American Quasar Petroleum Co.	Crown Zellerbach No. 21-41 (Columbia County)	NE¼ NE¼ sec. 21 T. 6 N., R. 4 W.	----
110	9-12-79	American Quasar Petroleum Co.	Laubach No. 24-11 (Columbia County)	NW¼ NW¼ sec. 24 T. 6. N., R. 5 W.	----



Study of geologic hazards of eastern Benton County released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has completed its *Geologic Hazards of Eastern Benton County, Oregon*, published as Bulletin 98. The author is James L. Bela.

The bulletin details the results of a year-long study intended to provide practical information about specific geologic hazards and engineering geology conditions in eastern Benton County. It will be useful to land use planners and land managers.

The text contains many illustrations and descriptions of such hazards as landslides, soil erosion, high ground water and ponding, stream erosion and deposition, and earthquakes.

In addition, Bulletin 98 includes four 7½-minute geologic maps and one 15-minute county-wide geologic map. Geologic hazards are shown on the maps.

Price of the complete bulletin is $9.00. Address orders to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, OR 97201. Payment must accompany orders of less than $20.00. □

DOE selects joint venture for negotiation of contract in Basalt Waste Isolation Program

The Department of Energy (DOE) has selected the joint venture of Kaiser Engineers, Oakland, California, and Parsons-Brinkerhoff, Quade and Douglas, Inc., San Francisco, for negotiation of a contract to provide architectural-engineering services to the Basalt Waste Isolation Program (BWIP).

The BWIP is responsible for assessing the feasibility and providing the technology to design and construct a licensed geologic repository for disposal of radioactive waste in the Columbia River Basalt Group, a 50,000 sq mi range of basalt running through parts of Washington, Oregon and Idaho.

Under terms of the contract, the joint venture will prepare a conceptual design of a basalt repository. Pending completion of negotiations, the two-year effort would be completed by September 1981 at a cost of approximately $4.5 million.

If ongoing site studies determine that the Hanford Site near Richland, Washington, is suitable for location of a repository, DOE has the option of continuing the services for preliminary and detailed design plus field services during construction. These site studies are being performed under the direction of DOE's Richland Operations Office by Rockwell Hanford Operations, a division of Rockwell International.

The BWIP is part of DOE's Nuclear Waste Terminal Program which is performing analysis characterizing various host rocks that show some potential as repository sites. Prior to any site selection for a repository, DOE will complete all the necessary steps required under the National Environmental Policy Act. □

Surface mine reclamation specialist position available

A surface mine reclamation specialist is needed by the State of Oregon Department of Geology and Mineral Industries. This position is with the Mined Land Reclamation Division. Primary reponsibilities include field inspections and enforcement. Considerable in-State travel required. This position requires technical education in one of the following fields: geology, forestry, engineering, or related fields. Preference will be given to applicants with specific experience in surface mine reclamation. Send resume and references to: Department of Geology and Mineral Industries, Mined Land Reclamation Division, 1129 S.E. Santiam Road, Albany, Oregon 97321, telephone: (503) 967-2039. □

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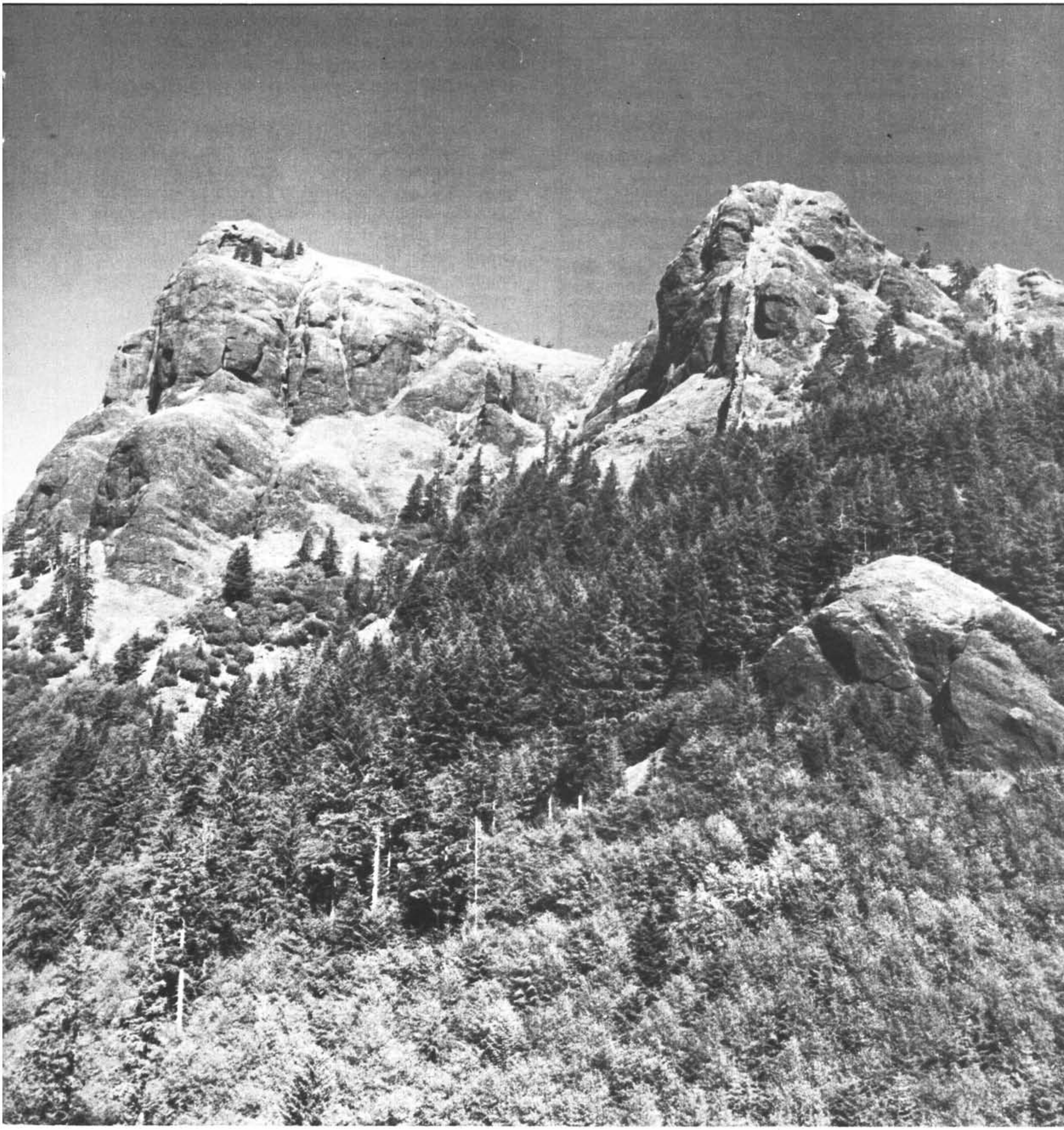

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COVER PHOTO

Saddle Mountain, western Oregon, of Miocene coastal basalt whose origin is discussed in the article beginning on the next page. Note narrow vertical dikes cutting the basaltic breccia that forms the mountain. (Oregon State Highway Division Photo)

Forecasts of future demand for rock materials in Oregon released

The Oregon Department of Geology and Mineral Industries has completed a project which estimates the future demand for rock materials in Oregon.

Concentrating on two types of material, crushed rock and sand and gravel, the study analyzes econometric and growth-rate models for the State as a whole; the Portland area; and Jackson, Lincoln, and Umatilla Counties. Forecasts were developed for the years 1985, 1990 and 2030, predicting a generally increasing demand for all rock materials.

The most reliable forecasts were made for the Portland area, indicating, for example, that the area may soon experience a shortage of readily available sand and gravel. The study is aimed at forecasting models for State-wide application. It includes detailed directions on how to use the methods for forecasts in other areas of Oregon. It can be used for relating estimated demand to resource inventories and as a guide for resource management and planning.

The project report, now available as the Department's Special Paper 5, is entitled *Analysis and Forecasts of the Demand for Rock Materials in Oregon.* Price per copy is $3.00. Orders should be addressed to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201. Payment must accompany orders of less than $20.00. □

GSOC luncheon talks announced

The Geological Society of the Oregon Country holds noon luncheon meetings on the first and third Fridays of each month in Room A, adjacent to the cafeteria, third floor, Standard Plaza, 1100 SW 6th Avenue, Portland. Illustrated topics and speakers include:

Oct. 19: Constructing the I-205 Columbia River bridge, Allen C. Harwood, Projects Engineer, Oregon State Highway Division.

Nov. 2: The Three Mile Island Incident, talk by Wilbur L. Nees, Senior Nuclear Engineer, Pacific Power and Light Company.

For additional information, contact Viola Oberson, Program Chairperson (282-3685). The meetings are open to the public. No reservations are required. Luncheons are available at the cafeteria. □

CONTENTS

The origin of the Miocene basalts of coastal Oregon and Washington: an alternative hypothesis

by Marvin H. Beeson, Earth Sciences Department, Portland State University, Portland, Oregon; Rauno Perttu, Bear Creek Mining Corporation, Spokane, Washington; and Janice Perttu, Earth Sciences Department, Portland State University

INTRODUCTION

Outcrops of Miocene tholeiitic basalt along the Pacific coast from Seal Rocks, Oregon, to Grays Harbor, Washington, have been mapped as "coastal basalts" (Schlicker and others, 1972; Beaulieu, 1973; Snavely and others, 1973, 1976a, b, c). The coastal basalts are mapped as flows, dikes, sills, and irregular intrusions, leading Snavely and others (1973) to conclude that they are of local origin. Snavely and others (1973) divide these basalts into three stratigraphic units in order of decreasing age: Depoe Bay Basalt, Cape Foulweather Basalt, and basalt of Pack Sack Lookout. These basalts are virtually identical in major element composition (Snavely and others, 1973; Bowman and others, 1974), trace element composition (Nathan and Fruchter, 1974; Bowman and others, 1974; Hill, 1975), isotopic composition (Tatsumoto and Snavely, 1969; McDougall, 1976), and relative stratigraphic position to the Grande Ronde Basalt, Wanapum Basalt, and Pomona Member, respectively, of the Columbia Plateau (nomenclature after Swanson and others, in press). The units of the coastal basalts are considered as correlative and consanguineous with the respective formations of the plateau (Snavely and others, 1973):

Plateau Units	Coastal Units
Pomona Member	Basalt of Pack Sack Lookout
Wanapum Basalt	Cape Foulweather Basalt
Grande Ronde Basalt	Depoe Bay Basalt

The Columbia River Basalt Group of the Columbia Plateau is the product of a series of eruptions from north- to northwest-trending groups of fissures now represented by dike swarms in eastern Oregon, eastern Washington, and western Idaho (Waters, 1961; Taubeneck, 1970; Swanson and others, 1975). These "plateau basalts" covered the Columbia Plateau and flowed westward through a broad gap in the Western Cascades into the Willamette Valley and along the Columbia River toward the coast, very near to and, in places, overlapping the mapped occurrences of the "coastal basalts."

We have reviewed the geologic maps and literature relating to the nature and origin of the coastal basalts (Layfield, 1936; Warren and others, 1945; Baldwin, 1952; Schlicker and others, 1972; Beaulieu, 1973; Snavely and others, 1973, 1976a, b, c; Choiniere and Swanson, 1979), have made a preliminary field study, and prefer an alternative hypothesis consistent with most published observations. Our hypothesis is that both the Columbia Plateau and the coastal Miocene basalts originated from plateau vents; the coastal basalts represent the distal ends of plateau-derived lava that flowed into estuarine and deltaic environments, invading and deforming soft sediments.

ORIGIN OF MIOCENE COASTAL BASALTS

Local eruption hypothesis

The generally accepted hypothesis that the coastal Miocene basalts originated by eruption from local vents is based on the presence of dikes and sills associated with the lava flows. This logic is convincing indeed and ordinarily would not be questioned, except that each of the three coastal Miocene basalts is consanguineous with, and apparently was erupted simultaneously and in the same sequence as, the correlative unit originating from vents 400-500 km distant in the Columbia Plateau. Thus we are confronted with some rather weighty problems of petrogenesis or subterranean magma transport. Could the upper mantle produce virtually identical sequences of magma in these widely separated and tectonically dissimilar regions and yield them for eruption at the same time? Or could a continuous, homogeneous magma chamber or conduit stretch from eastern Oregon and Washington to the coast, crossing the major north-south structural zone of the Cascade Range, and erupt identical magmas only at the ends, while magmas of different composition (e.g. andesites in the Cascades and the Prineville chemical type of the Columbia River Basalt Group near Prineville, Oregon) were erupted in between? The inadequacies of these and similar *ad hoc* hypotheses have prevented a consensus regarding the origin of the coastal Miocene basalts. If they are assumed to have erupted from local vents, then their origin is well characterized as a "petrogenetic enigma" (G. G. Goles, personal communication).

The extrusion of three different magmas in succession from widely separated vents calls for either a highly ingenious petrogenetic explanation or a questioning of the basic assumption that the presence of Miocene dikes and sills of basalt along the coast must mean local eruption. The terms "dike" and "sill" are descriptive, denoting tabular igneous bodies that are discordant and concordant, respectively, to the layering of the rocks they intrude. No specific origin should be implied when a descriptive name is assigned to a rock feature, but because most dikes and sills originate in the vicinity of vents, their presence is usually assumed to indicate that there are vents nearby. Because the assumption that the coastal Miocene basalts were emplaced as melts rising from local vents has so far led only to unsatisfactory petrogenetic hypotheses or to largely untestable hypotheses of subterranean magma transport, we think that the terms "dike" and "sill" should be considered here in a purely descriptive sense, separate from specific genetic implications, so that alternative hypotheses of origin may be examined.

An Alternative Hypothesis

As an alternative to the local vent hypothesis, we propose that the coastal Miocene basalts of Oregon and Washington are extensions of lava flows from the Columbia Plateau and that their common occurrence as dikes and sills is a consequence of the interaction of thick flows of dense, basaltic lava with soft, less dense, water-saturated sediments of estuaries and deltas over which they moved. We know of no modern example of such an event to use as a uniformitarian comparison. In fact, large basaltic eruptions originating from intraplate fissures have been somewhat uncommon throughout geologic time. The occurrence of such an event on continental crust so close to a topographically subdued coastline that huge amounts of lava could be poured into estuaries and deltas is even less probable. Lacking a uniformitarian example, we must turn to smaller scale examples of a similar nature and to extrapolation and nonempirical reasoning to arrive at an understanding of the processes that may have been operating.

During the time of Columbia River basalt extrusion, the region of today's Coast Range and adjacent shoreline apparently was characterized by very subdued topography. Upper Oligocene to lower Miocene deltas had extended the shoreline of Oregon and Washington westward to at least its present position (Snavely and Wagner, 1963). Water-saturated, low-energy sediments abounded in this deltaic and estuarine environment. We envision that the plateau basalts flowed across the Coast Range through topographic lows and into this coastal environment.

Examples of basalt-sediment interaction on a much smaller scale than that envisioned along the coastal area are described by Schmincke (1964, 1967) and by Byerly and Swanson (1978) in central Washington, where Columbia River basalt flows encountered local lake sediments. Schmincke (1964) states:

> "A basalt flow may advance over a sedimentary layer without much mechanical deformation, or it may form a peperite layer between the sediment and the bulk of the overlying lava. Basalt may invade downward into the sediments at various levels in a smooth sill-like fashion with remarkably little deformation of the sediments, or it may occur in irregular forms, in 'dikes,' lobes, or tongues of solid lava, as autobreccia, or peperite. Sediment layers may be gently lifted to the top of the basalt, or may be fragmented, bulldozed aside, and intermixed with the basalt. Certain soft or loose sediments, such as diatomite mud or vitric ash, are inducive to peperite formation, but bedded fluvial sands, with their better defined bedding and greater strength, do not easily form peperites. Many of these features indicate that the invading basalt lava must have been very fluid."

The Columbia River basalt flows, upon encountering the sediment of the coastal region, could have interacted with the sediments in a variety of ways similar to those described by Schmincke (1964). Various conditions, such as degree of sediment compaction and lithification, grain size, cohesiveness, water content, structure, and internal and external geometry of the sedimentary layers, would have controlled the processes.

The degree of interaction would have ranged locally from violent, with steam explosions and the formation of extensive peperites, to passive, with the lava penetrating to preferred sediment contacts and flowing along the contacts laterally as sills, cracking and rafting the overlying sediments and intruding them as dikes.

Basaltic lava would have ponded in local topographic lows such as coastal marshes, inlets, and deeper channels, as may have happened at Neahkahnie Mountain. Accumulating ponded basalt would overload and displace the underlying sediments, with accompanying sediment deformation and sliding. Tensional zones associated with deformation and sliding of the sediments adjacent to ponded basalt would be injected locally with basaltic dikes. This injection process would be aided if slide masses carried the chilled basalt margins with them, thereby exposing liquid basalt to the tensional zones. Shrinkage joints in the chilled margins of ponded basalt would also be injected locally with liquid basalt from the interiors, as may have occurred at Saddle Mountain (not to be confused with the Saddle Mountain Basalt of the Columbia Plateau) (Baldwin, 1952). The overloading of unconsolidated sediments with basaltic lava would also tend to liquefy water-saturated layers between less permeable, more cohesive layers, thereby producing clastic dikes, common in the sedimentary rocks of the area. Basalt flows that originally filled topographic lows may later have become the ridges of the area, as post-Miocene uplift and subsequent erosion of the softer surrounding sedimentary rocks inverted the topography.

Repeated basalt flow invasions of a coastal-deltaic environment, with accompanying basalt-sediment interaction, would have numerous consequences which cannot be discussed in this paper, but which may be the subject of future work.

OBSERVATIONS RELATING TO ORIGIN

Some observations made by geologists who have mapped and studied the coastal Miocene basalts are discussed below for their relation to the different hypotheses of origin. Although most of the evidence is circumstantial, the fact that a number of phenomena support our hypothesis merits consideration.

Areal distribution of plateau basalt and coastal basalt

Figure 1 shows that the north-south extent of the plateau-derived basalt in western Oregon and Washington is nearly the same as that of the coastal basalt. All of the plateau basalt units correlative with those found in the coastal area have been traced through the Cascades and into the Willamette Valley, except for the Pomona Member, which was probably intracanyon and highly localized through the Cascades (Beeson and Moran, 1979).

It should be noted that although Snavely and others (1973) identified three units within the coastal basalts, there are actually four different chemical types represented, since both high Mg and low Mg Depoe Bay Basalts are found (Hill, 1975). In addition, Depoe Bay Basalt may display two distinct normal and one reversed magnetization direction (Choiniere and others, 1976; Choiniere and Swanson, 1979; R. Simpson, personal communication), raising the total number of correlative units to at least five.

On the other hand, plateau basalt units that are not known to have flowed across the Cascades (e.g. members of the Saddle Mountains Basalt other than the Pomona) have not been identified among the coastal basalts. At least one basalt unit, the phyric Cape Foulweather Basalt, was emplaced at almost the same geologic instant at the coast as the correlative unit on the plateau, since both record a geomagnetic field excursion (Choiniere and others, 1976; Choiniere and Swanson, 1979). Unpublished paleomagnetic data on the phyric Frenchman Springs Member of the Wanapum Basalt at Oregon City also show this same excursion (S. Sheriff, personal communication). The plateau basalts needed to flow only a short distance from the Willamette Valley across the then poorly developed Coast Range to reach the coast. Along the Columbia River, flows of plateau-derived basalt are shown to have terminated rather abruptly, usually before reaching the Miocene coastline (Snavely and others, 1973). However, 400 m of subaerial basalt is exposed along the Columbia River just 40 km east of the present coast (Niem and Van Atta, 1973), adjacent to rock mapped as coastal basalt.

It may well be assumed that lava that flowed through the Cascades and into the Portland area, and was able to flow 100 km south up the ancestral Willamette Valley could also have flowed approximately the same distance down-gradient to the ocean.

Nature of occurrences of coastal basalt

In most cases, the coastal basalts are associated with soft sediment (Snavely and others, 1973). Dikes and sills are mapped mostly within Oligocene-Miocene sedimentary rocks (Schlicker and others, 1972; Beaulieu, 1973; Snavely and others, 1976a, b, c). Older or lithified sedimentary rocks are seldom associated with these intrusives, despite the extensive occurrence of Eocene formations. Figure 2 shows the relationship between coastal basalt occurrences and post-Eocene sediment distribution. The outcrops of coastal basalt within Eocene sedimentary rocks in the vicinity of Mt. Hebo are a notable exception that may represent a lava-filled erosional channel through which the basalt crossed the Coast Range. This Mt. Hebo locality is a prime candidate for more detailed study.

Palagonite and peperites are commonly present there, indicating that the basalt was interacting with water and water-saturated sediments near the sediment-water interface, probably at and near sea level, and pillow basalts are often associated with considerable palagonite. Whereas glassy pyroclastic breccias are common, vesiculation is uncommon—a notable contrast to vent areas in the plateau.

Structural control of coastal vents

No consistent orientation of dikes is evident, indicating the apparent lack of a regional stress pattern, such as was present in the Columbia Plateau. In most cases, in fact, the dikes can be described as irregular rather than tabular masses. Dikes are often sinuous, and the Youngs River dike even resembles an oxbow in plan view. The only tectonic control of the "intrusives" appears to be the straight coastline, except where they follow the Oligocene-Miocene sedimentary rocks inland

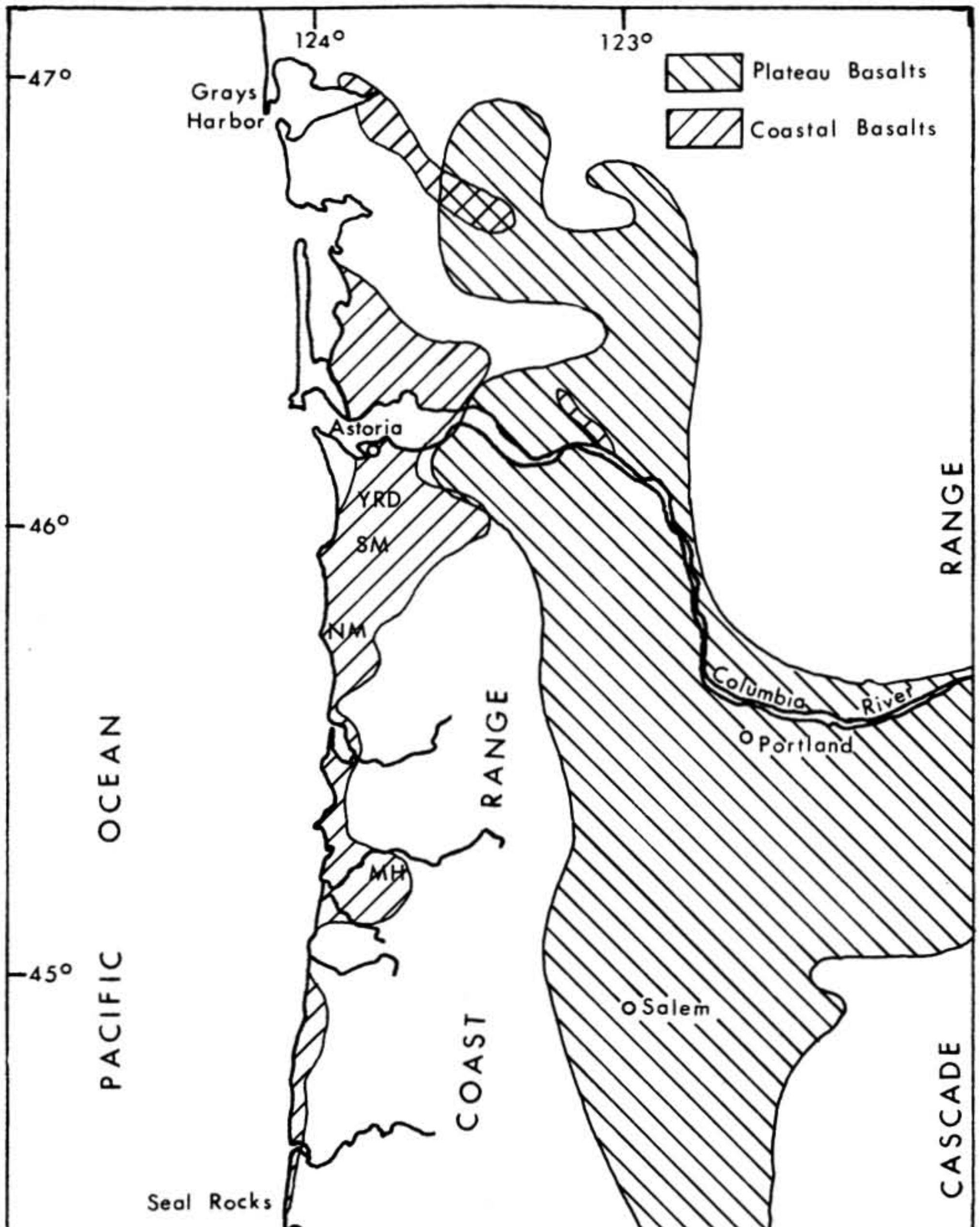

Figure 1. Areal distribution of plateau and coastal basalts in western Oregon and Washington (modified from Snavely and others, 1973). NM = Neahkahnie Mountain, SM = Saddle Mountain, MH = Mt. Hebo, YRD = Youngs River dike.

at the mouth of the Columbia River. Recent detailed mapping in the Tillamook Highlands shows most Eocene dikes to have a dominant north-northwest trend (K. Cameron, personal communication), indicating an Eocene coastal stress environment similar to that of the plateau at the same time. Layfield (1936) made some interesting observations concerning the dikes in the vicinity of Saddle Mountain, Oregon:

> "The dikes intruded in the breccia are the same type of rock as that intruded in the mica clay shales but differ in dimensions and somewhat in structure. Whereas the dikes of the mountain are seldom over 10 feet wide, dip 50°-90°, and are limited in extent, those in the shales have low dips, are 20-200 feet wide and run for thousands of feet.
>
> * * * * *
>
> "No evidence is found that the dikes extend over ¾ of the way down the mountain. Some pinch out entirely" (p. 8).

Snavely and others (1973) interpret the vents to be more localized than the elongate dike swarms of the plateau. In that case, one might expect volcanic cones to form and, after erosion, to display resistant plugs and dikes. At some point in their lifetime, smaller volume central eruptions also tend to produce lavas that show some chemical differentiation. Few of these features or differentiated lavas seem to be present along the coast. Ring dikes of Cape Foulweather Basalt at Cape Foulweather are also considered to be evidence of local vents (Snavely and others, 1973). Recently, very similar structures in basalts of the plateau were interpreted as originating through interaction of ground water with basaltic lava unrelated to vents (Hodges, 1978).

Associated sedimentary structures

Deformation is usually present in the Miocene sedimentary rocks adjacent to the basaltic intrusives, as shown by the attitude of beds as mapped by Snavely and others (1973). Much of this deformation has generally been attributed to post-basalt tectonism. While large-scale, post-Miocene warping has occurred in the region, we believe that much of the sediment deformation near the basalts occurred as a result of invasion of the sediments by the basaltic lava flows. Simpson (personal communication) recently re-evaluated paleomagnetic data on the Cape Foulweather Basalt in light of the plateau origin hypothesis and discovered that paleomagnetic poles plotted with little scatter when no corrections were made for apparent post-basalt deformation, whereas considerable scatter existed when corrections for attitudes of associated sedimentary rocks were considered.

These preliminary data strongly suggest penecontemporaneous sediment deformation with the emplacement of basaltic lava. Although some sediment deformation could result from local venting, we would expect considerably more from invasive flows. In addition, deformation is necessary to our hypothesis, since dike injection is greatly accommodated by this process.

TESTS FOR ORIGIN HYPOTHESES

Having proposed an alternative to the local vent hypothesis, we wish to mention studies which may help to test these two opposing hypotheses. The following studies have been planned or have already begun:

Detailed mapping of each basalt unit

If the coastal basalts are of plateau origin, then detailed mapping of each unit through western Oregon to the coast should show the paths taken by each unit in reaching the coast. Except along the Columbia River, little Columbia River basalt has been found in the Coast Range, where it may have been lost through erosion during uplift of the range. Both high Mg and low Mg Grande Ronde and Wanapum Basalts have recently been identified by trace element chemistry in the Willamette Valley as far south as Stayton, Oregon (Beeson and others, 1976). We might expect that after each lava flow filled an estuary, the stream would re-establish itself marginal to the lava flow, thereby preparing the path of the next lava flow. Identification by neutron activation analysis of mapped basalt occurrences from the Cascade Range to the coast is planned.

Geophysical studies to determine depth of dikes

Gravity studies are currently being carried out across some of the larger dikes in an attempt to estimate their vertical extent. Preliminary traverses across the Youngs River dike indicate that it cannot be interpreted as a deep vertical dike (V. Pfaff, personal communication). Seismic refraction and magnetic studies are also planned across this and other selected dikes.

Paleomagnetic pole determinations

Paleomagnetic poles are being determined in order that syn- or post-depositional deformation of intruded sedimentary rocks may be assessed. Preliminary data exist, and more work is planned (R. Simpson, personal communication). These measurements will be carefully associated with geochemical studies for basalt correlation.

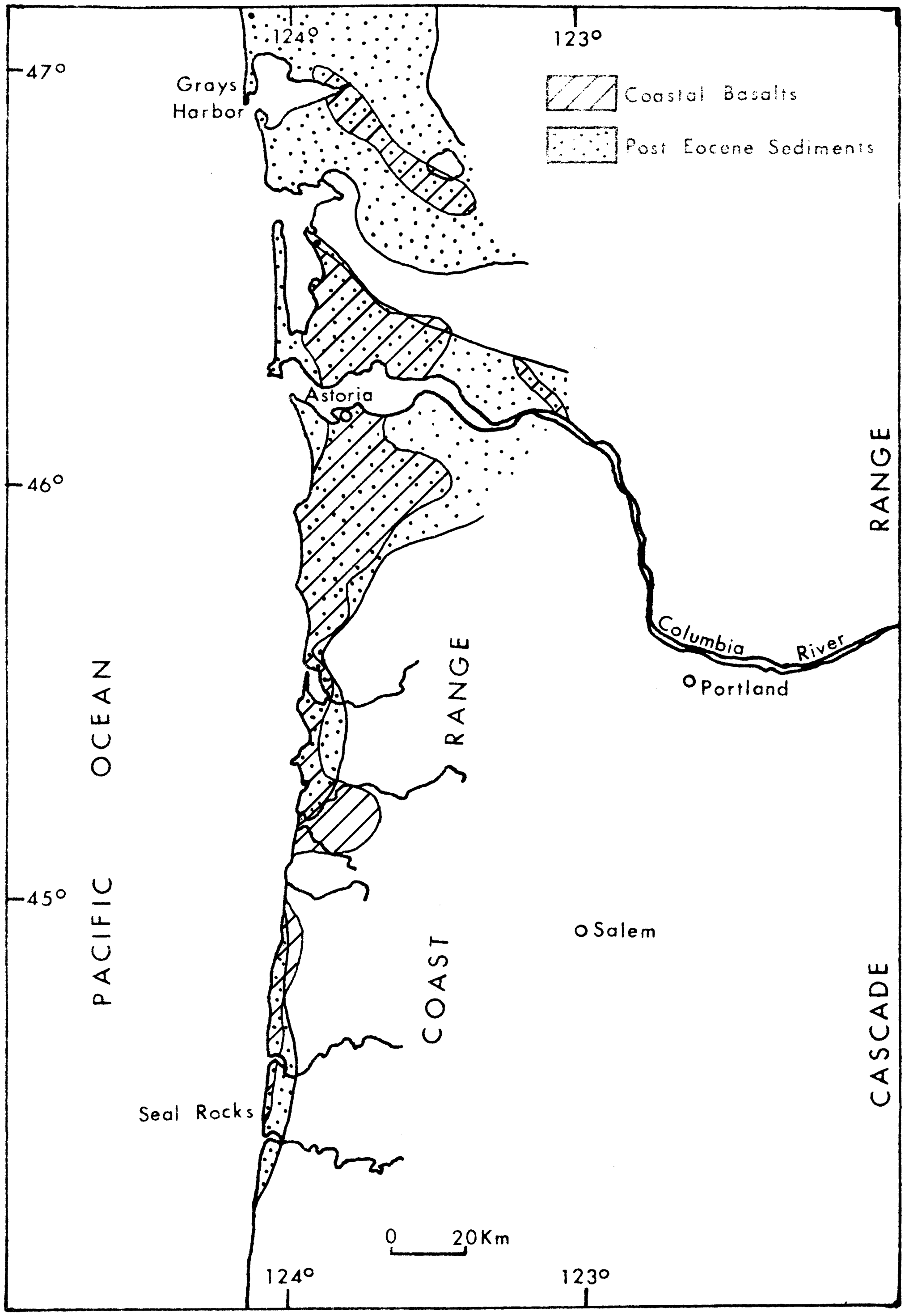

Figure 2. Areal distribution of coastal basalts and post-Eocene sediments in western Washington and Oregon (modified from Snavely and others, 1973).

CONCLUSION

The hypothesis that the coastal Miocene basalts of Oregon and Washington originated by eruption from local vents results in severe petrogenetic problems since the coastal basalts are virtually identical with basalts of the Columbia River Basalt Group from the Columbia Plateau. We propose an alternative hypothesis suggesting that the coastal basalts are not of local origin but are the extension of flows from the plateau into estuarine and deltaic environments. This alternative hypothesis introduces problems, mostly mechanical in nature, but we consider them minor in comparison to the mechanical problems of up to 500 km of subterranean magma transport or the unlikely petrogenetic coincidence of separate but identical evolution of four chemically distinct types of magma. Our hypothesis exchanges local mechanical problems for regional mechanical or major petrogenetic ones. We think consideration of the effects of loading metastable estuarine and deltaic sediment accumulations with dense basaltic lava and the resulting interactions with soft sediments can produce reasonable explanations for most local modes of occurrence. More geochemical and geophysical studies are planned to help evaluate the alternative hypothesis of the coastal basalt origin.

ACKNOWLEDGMENTS

The authors wish to thank Ewart M. Baldwin, Robert Simpson, and Donald A. Swanson for reviewing and commenting on this paper. One author, Marvin H. Beeson, wishes to acknowledge that in 1976 Donald A. Swanson discussed with him the similarity of the Miocene coastal and plateau basalts. At that time, Swanson expressed reservations concerning the local vent origin of the coastal basalts but said that certain field relationships shown to him by Norm MacLeod strongly supported the hypothesis of local vent origin.

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COVER PHOTO

Heceta Head, a promontory of late Eocene basalt on the central Oregon coast. Article beginning on next page presents geophysical and geological cross sections of this portion of the continental margin. (Photo courtesy Oregon State Highway Division)

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CONTENTS

Geology of the continental margin near Florence, Oregon

by Richard Couch and David Braman, Geophysics Group, School of Oceanography, Oregon State University, Corvallis, Oregon

ABSTRACT

Compilations of well-log and geophysical data from investigations of rocks on the submarine continental margin and landward of the coast of central Oregon yield geophysical and geological crustal cross sections of the margin near Florence, Oregon. The sections show that oceanic crust 12 to 15 My old dips beneath the continental slope and outer continental shelf and that the magnetic basement, coincident with the Siletz River Volcanic Series landward of the coast, extends and deepens seaward to the continental slope. Approximately 2 to 5 km of sediments that include Tertiary rocks similar to the Flournoy, Nestucca, and Coaledo Formations, overlie the early Eocene volcanic series. The configuration of the rock units in the crustal section suggests that deformation of the units, attributable to plate convergence, is greatest near the outer margin of the continental shelf and decreases landward and that folding and faulting have uplifted the sedimentary layers that are above the magnetic basement to form a structural high along the outer continental shelf.

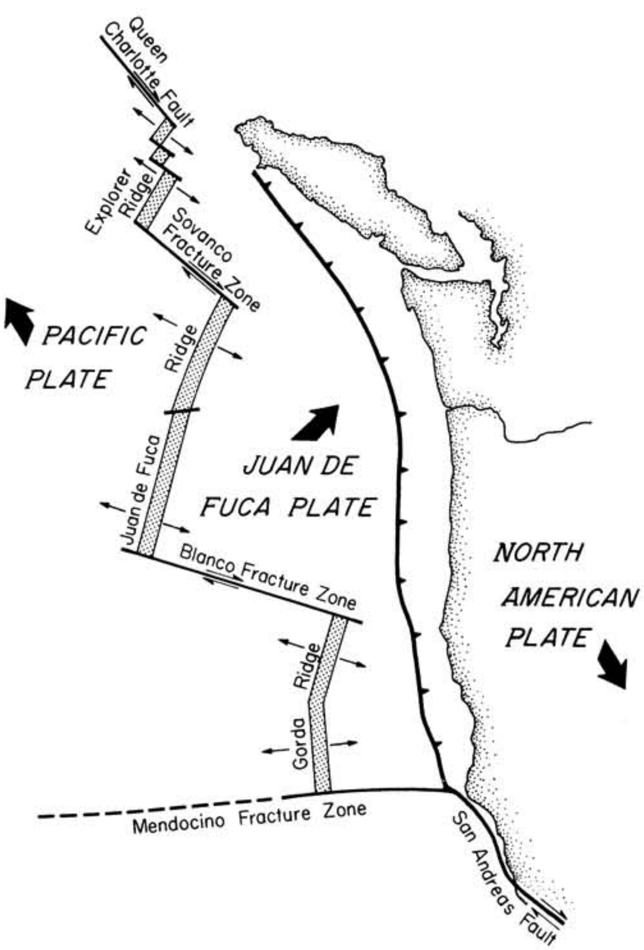
INTRODUCTION

Major fracture zones and mountainous ridges mark certain types of active boundaries between large lithospheric plates. Figure 1 schematically shows the kinematics of the plates off the coast of the Pacific Northwest. The San Andreas fault system in California and the Queen Charlotte-Fairweather fault system in British Columbia and southeastern Alaska comprise the transform faults along which the Pacific and North American Plates slide past one another in a right-lateral sense.

Between the San Andreas and Queen Charlotte-Fairweather transform faults, sea-floor spreading occurs along the Gorda, Juan de Fuca, and Explorer ridges as the Pacific and Juan de Fuca Plates diverge. The Blanco and Sovanco fracture zones, both right-lateral transform faults, offset the spreading ridges. The Juan de Fuca Plate moves toward the northeast relative to the North American Plate as a consequence of plate divergence approximately normal to the spreading ridges and right-lateral plate motion along the San Andreas and Queen Charlotte-Fairweather transform faults.

Convergence of the Juan de Fuca and North American Plates and subsequent oblique underthrusting of the Juan de Fuca Plate beneath the North American Plate occurs along the base of the continental slope off Oregon, Washington, and southern British Columbia. The direction of motion of the Juan de Fuca Plate relative to the continental slope off Oregon is toward but oblique to the strike of the slope, and the rate of convergence is estimated to be approximately 2 cm/yr (Atwater, 1970). However, migration and changes in the orientation and number of ridges and fracture zones during geologic time have caused marked changes in the directions and velocities of plate convergence along the continental margin and in the composition and structure

Figure 1. Plate tectonic motions in the northeast Pacific. Arrows indicate the general direction of relative motion of the Pacific, North American, and Juan de Fuca Plates.



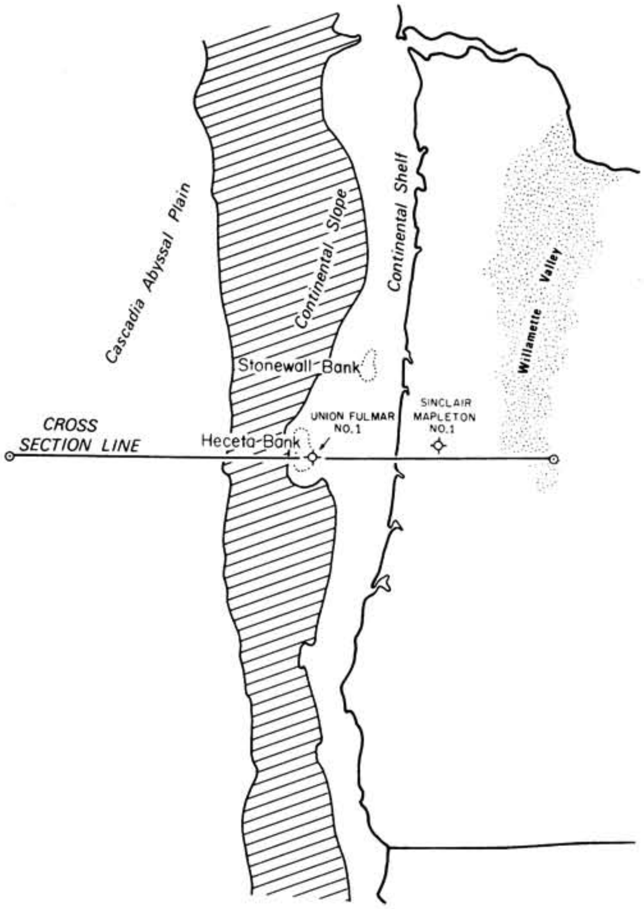


Figure 2. Geomorphology of the continental margin near Florence, Oregon.

of the accreted and subducted materials.

Along the continental slope off the Pacific Northwest coast, sea-floor sediments are carried landward during plate convergence. At the subduction zone, some of these sediments apparently are scraped off of the oceanic plate, accreted to the continental plate, and subsequently uplifted and emplaced in the continental slope (Byrne and others, 1966; Kulm and Fowler, 1974). Seely and others (1974) proposed an imbricate thrust model, wherein wedges of sediments are thrust successively one under another at the base of the slope, to explain the uplift and emplacement of deep-sea sediments on the continental slopes of convergent continental margins. Kulm and Fowler (1974) have shown that the imbricate thrust model is consistent with the composition, ages, and paleodepths of the sedimentary units which form the continental slope and outer continental shelf off the central Oregon coast. However, because data are sparse on the geology of the continental margin, it is not known to what extent the imbricate thrust model, when complicated by changes in the rates and directions of plate convergence, can explain the composition, structure, and evolution of the continental margin. The purpose of this paper is to summarize the geophysical data obtained from the continental margin off the central Oregon coast near Florence, to present a geophysical model constructed to be consistent with the data, and to offer an interpretation of the model in the form of a geological crustal section.

GEOMORPHOLOGY OF THE CENTRAL OREGON CONTINENTAL MARGIN

In Oregon, the zone of transition between true oceanic and continental crust extends from the deep-sea floor of Cascadia Abyssal Plain west of the continental slope to at least the high plateaus east of the Cascade Mountain Range. The transition zone includes the continental slope and continental shelf, which together comprise the submarine continental margin. Figure 2 outlines the general geomorphology of the central Oregon continental margin.

The continental shelf dips gently seaward and reaches depths of 200 to 300 m approximately 30 km seaward of the coast. Off Florence, the continental shelf is approximately 60 km wide and shoals to depths of less than 45 m over Heceta Bank on the outer continental shelf. Seaward of the continental shelf, the relatively steep continental slope descends to abyssal sea-floor depths of approximately 3,000 m. North of Heceta Bank, a series of north-to-northwest trending ridges occur on the slope in water depths of more than 1,000 m (Braislin and others, 1971; Kulm and others, 1973; von Huene and Kulm, 1973; Snavely and others, 1977). Figure 2 shows that the geographical and geological cross sections of Figure 3 and Figure 5 are oriented approximately normal to the continental margin and pass through the south end of Heceta Bank.

MEASUREMENTS AND DATA

Figure 2 shows the line along which the Florence crustal and subcrustal cross section was constructed. The section extends from a point in Cascadia Abyssal Plain, approximately 200 km west of the coast, to the east side of the Willamette Valley. The section intersects the south end of Heceta Bank and the Union Fulmar No. 1 well, located on the continental shelf west of Heceta Head, and passes south of the Sinclair Mapleton No. 1 well, located north of Mapleton, Oregon. Logs of the two deep wells; bathymetric, gravity, magnetic, and seismic reflection and refraction measurements at sea; and topographic, geologic, gravity, and aeromagnetic observations on land constrain the geophysical model section.

Shor and others (1968) made seismic refraction measurements on the continental shelf west of the

Union Fulmar No. 1 well and in Cascadia Abyssal Plain along lines parallel to the continental margin. Their measurements provide data on the depth and seismic velocities of the crustal layers and top of the mantle. Sonobuoy refraction measurements (Keser, 1978) near the section provide thicknesses and velocities of the sedimentary layers overlying the oceanic crust seaward of the slope and the shallow layers on the continental slope and shelf. Seely and others (1974) show a multichannel seismic reflection profile shot by Exxon along the section line from the abyssal plain to a point east of the Union Fulmar No. 1 well. The reflection line provides information on water depths and the thicknesses of the sedimentary layers above the abyssal sea floor and above an acoustic basement on the continental margin. When reduced to anomaly values by removal of appropriate regional fields (International Association of Geodesy, 1971; International Association of Geomagnetism and Aeronomy, 1976), gravity and magnetic measurements made by the National Ocean Survey (National Oceanic and Atmospheric Administration, 1978) yield gravity and magnetic data along the marine portion of the section. Gravity anomalies reported by Thiruvathukal (1968) and aeromagnetic measurements reported by Bromery (1957) provide control for the land portion of the section. The empirical relations between seismic velocity and density (Ludwig and others, 1970) and well-log data guided the selection of model densities. The crustal section assumes a two-dimensional structure, a standard mass column of 50 km and 6,442 mgals corresponding to a zero free-air gravity anomaly (Barday, 1974), and no lateral variations in density below 50 km depth. Iterative adjustments of layer boundaries, constrained by water depth, land elevation, abyssal sediment thickness, refracting horizons, and horizons determined from the well logs, were made until the gravity, computed with the method of Talwani and others (1959) and Gemperle (1975), agreed with the observed free-air and Bouguer anomalies, and the magnetic intensity, computed by the method of Lu and Keeling (1974), agreed with the observed magnetic intensity. This yielded the Florence geophysical cross section.

THE FLORENCE CRUSTAL AND SUBCRUSTAL CROSS SECTION

Figure 3 shows the Florence geophysical cross section. The section, approximately 300 km long, is oriented N 91° E normal to the continental margin and intersects the coastline north of Florence, Oregon. The crystalline oceanic crust at the seaward end of the section is approximately 6 km thick and is composed of a lower crustal layer with a density of 2.95 gm/cm^3 and an upper layer with a density of 2.65 gm/cm^3. More than 1 km of sediments, with an average density of 1.85 gm/cm^3, overlie the basaltic rock of the upper oceanic crust. The total thickness of the oceanic crust of Cascadia Abyssal Plain, including 3 km of water, is approximately 10 km.

The topmost lines of Figure 3 show the observed magnetic anomalies over the section and, for comparison, the theoretical sea-floor magnetic anomalies which assume an apparent half-spreading rate of 2.0 cm/yr and use the magnetic time scale of Blakely (1974) and Ness and others (1980). A good correlation exists between the observed and theoretical magnetic anomalies over the abyssal plain extending to just landward of the continental slope. The magnetic anomalies indicate that the age of the oceanic basement rock ranges from approximately 8 My (anomaly 4'.1) to 11.7 My (anomaly 5A).

The crystalline oceanic crust dips landward, and the depth to the top of the mantle beneath the continental shelf is 15 to 20 km. Few gravity data and no seismic data are available to constrain or resolve the continental section, indicated by the blocks of density 2.35, 2.60, 2.70, and 2.95 gm/cm^3 east of the coast line. However, the computed gravity based on the depicted structure and constrained by a standard mass column suggests that the depth to the top of the mantle is approximately 20 to 25 km beneath the Coast Range of the central portion of western Oregon.

On the continental shelf, a thick sedimentary basin, indicated by a 15 mgal negative gravity anomaly and composed of sediment layers with densities of 1.80, 1.90, 2.20 and 2.35 gm/cm^3, deepens seaward. Near the outer edge of the continental shelf, the 2.20 and 2.35 gm/cm^3 sediment layers rise steeply toward the surface beneath Heceta Bank and cause a marked positive gravity anomaly. The sedimentary layers overlie material which has a density of 2.60 gm/cm^3 and a magnetization of 0.005 emu/cm^3. These rocks, identified in the Sinclair Mapleton No. 1 well as members of the Siletz River Volcanic Series, extend from the eastern slopes of the Coast Range to the middle of the continental slope. Near the coast, other rocks identified as Yachats Basalt (Snavely and MacLeod, 1974), with a density of 2.60 gm/cm^3 and magnetization of 0.001 emu/cm^3, extend seaward beneath a thin cover of sediments. Connard and Levi (1979, personal communication) have used direct methods to identify other magnetic sources near the interface between the 2.20 and 2.35 gm/cm^3 layers.

A large block of material of density 2.15 gm/cm^3 underlies the continental slope and is interpreted as accreted oceanic and continental sediments. A relatively thin veneer of continental sediments of varying thickness overlies the accreted sediments of the slope. The section also shows layers of density 2.30 and 2.50 gm/cm^3 beneath the sediments of Cascadia Abyssal

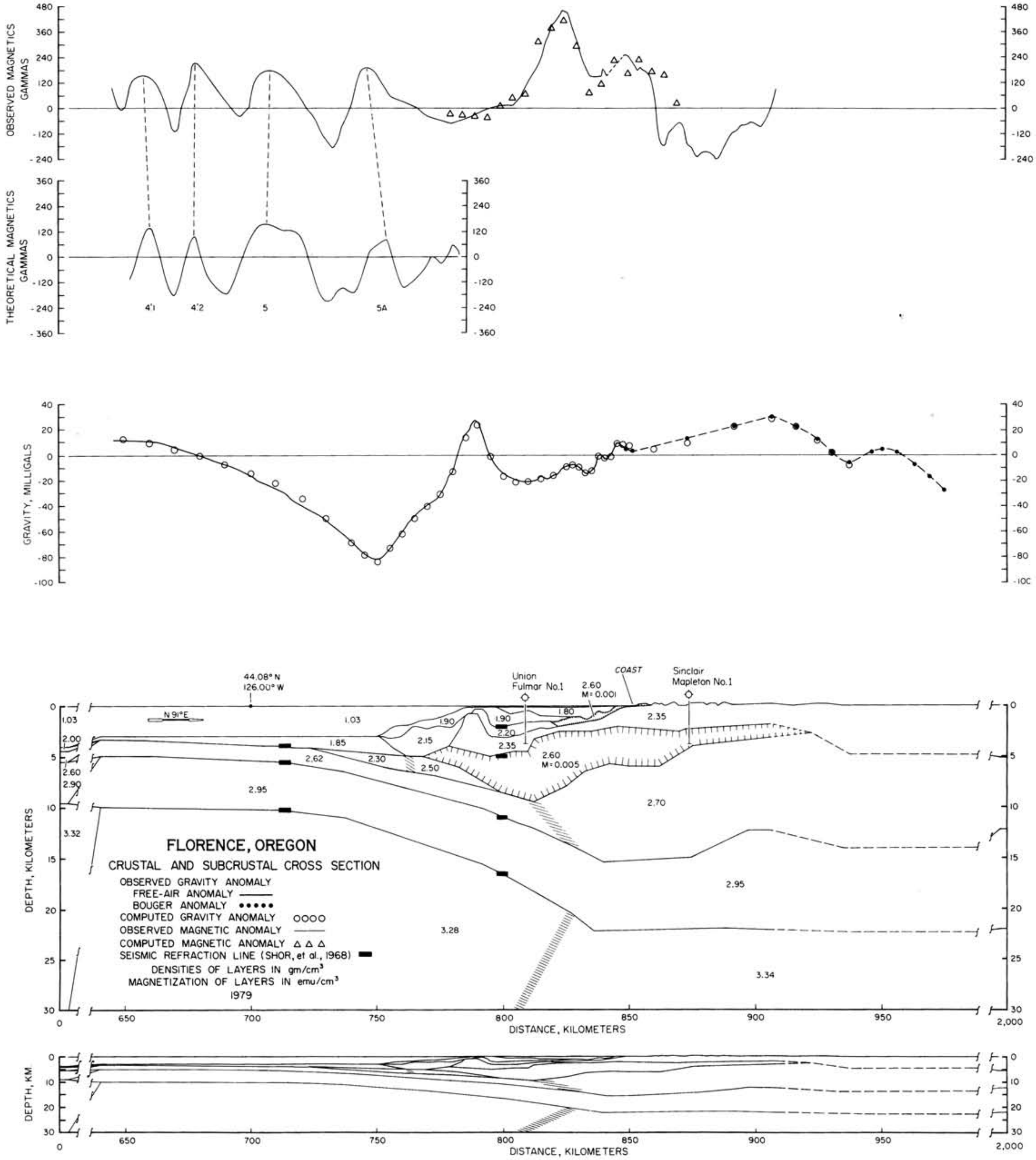


Figure 3. Geophysical crustal and subcrustal cross section. The section, oriented approximately east-west, extends from Cascadia Abyssal Plain to the east side of the Willamette Valley.

Plain and beneath the continental slope, respectively. The layer of 2.30 gm/cm^3 is visible on multichannel seismic reflection records (Seely and others, 1974) and is interpreted as partially compacted oceanic sediments which overlie the acoustic basement. The block of 2.50 gm/cm^3 is also interpreted as sediments, but here they are thrust beneath rocks of the denser Siletz River Volcanic Series, resulting in an even greater density increase caused by additional compaction and dewatering.

Below the annotated section, which has a vertical exaggeration of 4:1, an unexaggerated 1:1 section is illustrated.

Figure 4 shows a free-air gravity anomaly map of the central Oregon continental margin adapted from Dehlinger and others (1970). An elongate negative gravity anomaly, which reaches values of −100 mgals, occurs along the base of the continental slope. The axis of the negative anomaly approximately coincides with the base of the continental slope. As shown in Figure 3, the landward dipping oceanic crust and an increasing thickness of relatively light sediments, including those of the lower slope, cause the negative anomaly. The gravity map shows that the positive anomaly caused by the shoaling of denser sedimentary rocks extends north along the outer continental shelf. The continuity of the anomaly suggests that similar structures exist beneath the northern end of Heceta Bank and also possibly beneath Stonewall Bank, west of Newport, Oregon. South of Heceta Bank, a large negative gravity anomaly, which reaches values of −60 mgals, outlines a sedimentary basin whose center is located near the middle of the continental shelf west of Reedsport. The anomaly values suggest that sediment thicknesses may exceed 7 km. The sedimentary layers of the shelf above the magnetic basement shown in Figure 3 and found in the Union Fulmar No. 1 well are in the northern end of the basin. The anomaly gradients suggest that these layers probably thicken toward the south and that the outer structural high, formed by the shoaling of the deeper sedimentary layers, decreases in amplitude.

THE FLORENCE GEOLOGICAL SECTION

Figure 5 shows a geological interpretation of the geophysical section. Geological information is provided by the lithologic logs of the Union Fulmar No. 1 and Sinclair Mapleton No. 1 wells; by Deep-Sea Drilling Project holes drilled in Cascadia Basin (DSDP Site 174) and in the continental slope (DSDP Site 175) north of the section (Kulm, von Huene, and others, 1973); by marine core data (Kulm and Fowler, 1974); by studies of the geology of western central Oregon (Snavely and Vokes, 1949; Baldwin and Beaulieu, 1973; Baldwin, 1975, 1976; Snavely and others, 1977); and by the physical parameters, depths, and continuity of horizons provided by the geophysical data.

Magnetic anomalies indicate that the oceanic crust beneath the sediments is middle to late Miocene in age. The oldest identifiable anomaly along the section is about 12 My old. However, the model suggests that the oceanic crust is continuous beneath the continental slope and the outer continental shelf. If this is correct, then the outer shelf sediments overlie oceanic crust approximately 15 My old. The oceanic sediment in contact with the sea-floor basalt is approximately the same age as the basalt and decreases in age upward. Multichannel seismic reflection data show acoustic horizons in the sediments indicative of unconformities (Seely and others, 1974). These were also observed in the cores at DSDP Site 174 (Kulm, von Huene, and others, 1973). The geologic section indicates only the unconformities between the Miocene-Pleistocene and late Quaternary and between the Miocene-Pleistocene and late Miocene. Cores from DSDP Site 175 indicate that late Pleistocene muds of the continental slope overlie partially consolidated mudstones and silt turbidites from the adjacent abyssal plain (Kulm, von Huene, and others, 1973). The interpretation of multichannel reflection data by Seely and others (1974) suggests that these deposits are a series of imbricate thrusts. Penetration of the abyssal plain deposits in the lowermost part of the section at site 175 also suggests imbrication of the sediments (Kulm, von Huene, and others, 1973; Kulm, 1979, personal communication).

Lithologic logs of the Mapleton Sinclair No. 1 well indicate that the hole penetrated approximately 2.5 km of rocks of the Flournoy Formation and about 1.5 km of rocks of the Siletz River Volcanic Series. Baldwin (1975, 1976) describes rocks of the Flournoy Formation as graded micaceous and arkosic sandstones and sandy siltstones. These rocks of middle Eocene age are found also in the Union Fulmar No. 1 well offshore and are interpreted to be the major constituent of the structural high beneath Heceta Bank. The nature of the contact between these middle Eocene rocks and the Tertiary volcanic rocks of the Cascade Range is unknown. Sedimentary rocks of late Eocene age overlie rocks of the Flournoy Formation. These rocks are thought to be similar to the tuffaceous shale, siltstone, sandstone, and interbedded volcanic rocks of the Nestucca Formation, described by Snavely and Vokes (1949), and/or the coarse-grained, nodular sandstone with intercalated shale beds of the Coaledo Formation, described by Baldwin and Beaulieu (1973). These rocks are apparently capped by late Miocene siltstones and claystones (Kulm and Fowler, 1974).

The lower section of the Siletz River Volcanic Series, which underlies the Flournoy Formation, is considered to be formed of upper oceanic crustal rocks, whereas the upper part of the series is thought to have

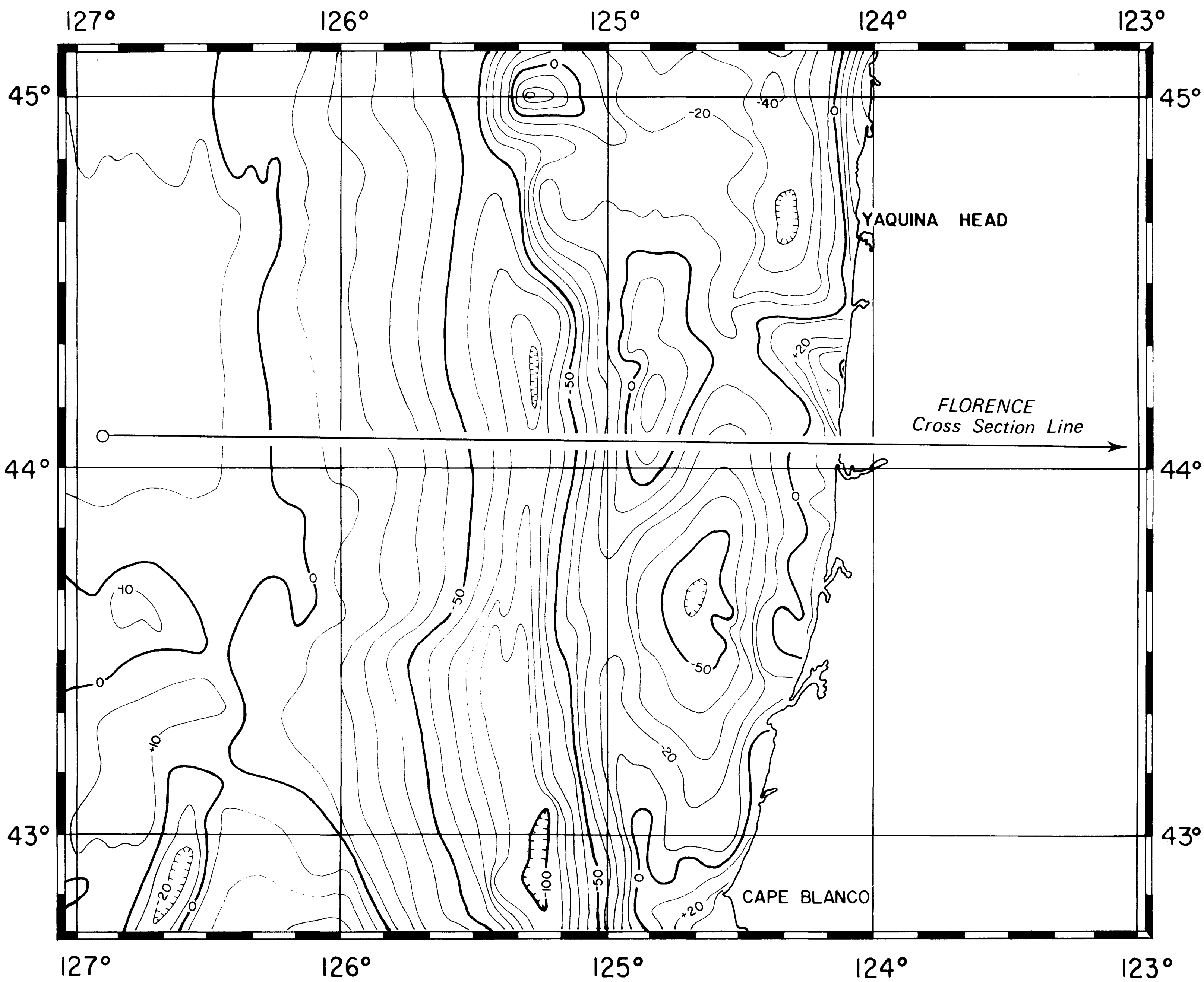


Figure 4. Free-air gravity anomaly map of the area offshore of the central Oregon coast (after Dehlinger and others, 1970). The line north of the 44th parallel indicates the location of the crustal cross sections of Figures 3 and 5.

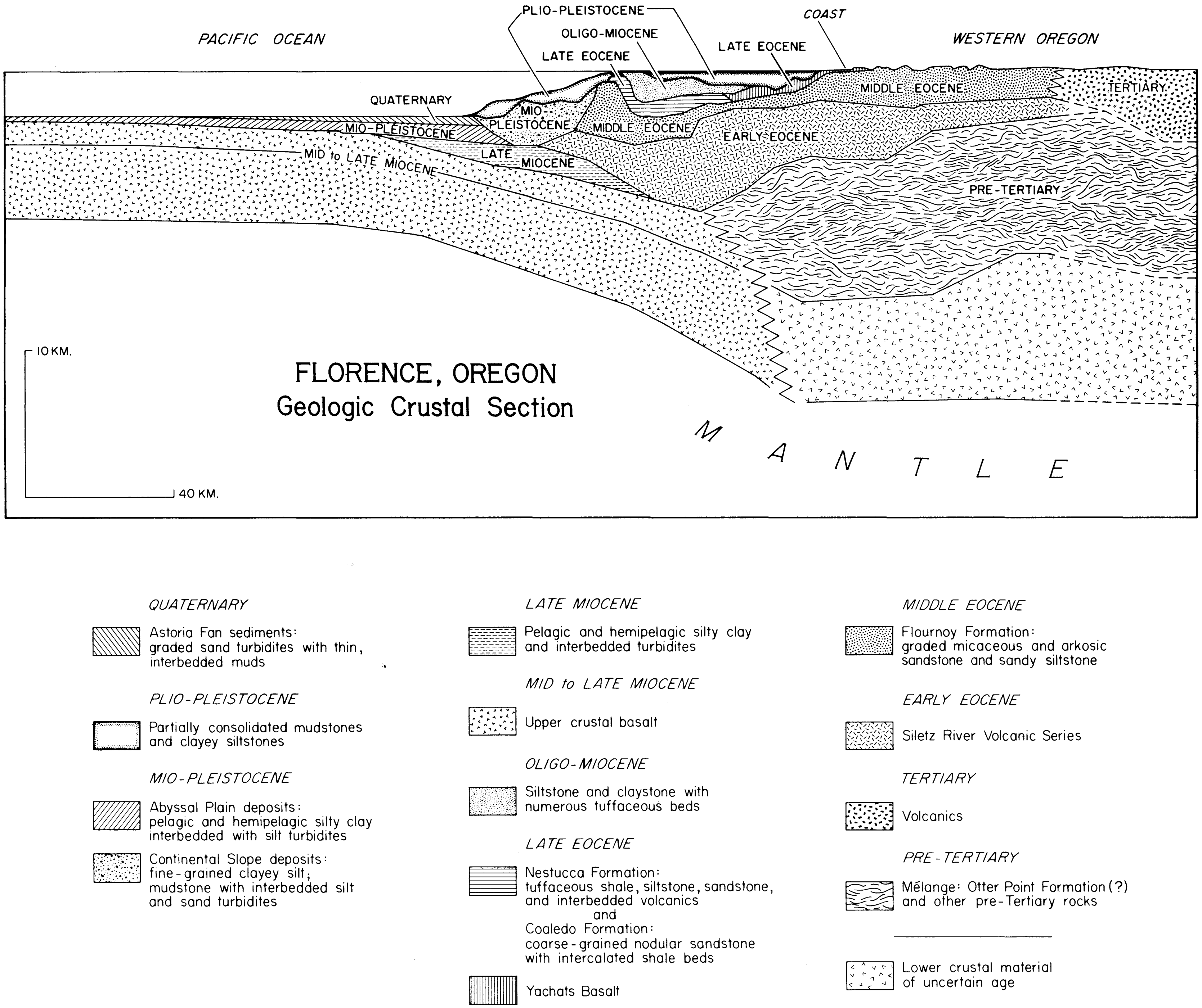


Figure 5. Geologic crustal section of the central Oregon continental margin north of Florence, Oregon.

been deposited in shallower water (Snavely and Baldwin, 1948; Baldwin, 1976; Snavely and others, 1977). This sequence of rocks apparently extends from near the base of the continental slope on the west to the Tertiary volcanic rocks of the Cascade Range and has its thickest section beneath the continental shelf. The nature of the pre-Tertiary rocks beneath the Siletz River Volcanic Series is unknown. Baldwin (1979, personal communication) suggests the rocks may be a mélange similar to the late Jurassic Otter Point Formation described by Kock (1966).

The landward dip of the westernmost part of the Siletz River Volcanic Series, as depicted in the geological section, suggests that this section of the series may have been carried or thrust landward beneath the same rocks nearer the present coast by the subducting oceanic crust, thereby foreshortening the continental margin and apparently thickening the volcanic sequence beneath the continental shelf. In this process, the westernmost ends of the overlying beds of the Flournoy Formation, the Nestucca/Coaledo Formation, and other Oligocene-Miocene sedimentary rocks were folded, faulted, and thrust upward to create an outer structural high that is manifested in the bathymetry as Heceta Bank.

Although the depth to the base of the Siletz River Volcanic Series is not well constrained by the available data, the configuration of the interface between the volcanic series and the underlying pre-Tertiary mélange suggests that the mélange also has been deformed contemporary with the deformation and uplift of the volcanic series. The deformation of the major crustal units appears to be greatest near the upper continental slope and outer continental shelf and to diminish toward the Willamette Valley.

CONCLUSIONS

The familiar rock units of western Oregon extend westward off the central Oregon coast to the edge of the continental shelf, and the oceanic crust of Cascadia Abyssal Plain has underthrust the continental margin eastward to at least the center of the continental shelf. The process(es) of thrusting or subduction profoundly influenced the conformation of the rock strata which form the continental margin. The convergence of the oceanic lithospheric plates and the continental plate appears to have uplifted and emplaced marine sediments in the continental slope, foreshortened the outer continental margin off the central Oregon coast, and folded and thrust up the sedimentary rocks to form an outer shelf structural high. Clearly, the geology of the margin is more complex than the models heretofore advanced have been able to explain.

ACKNOWLEDGMENTS

Discussions with Ewart M. Baldwin and LaVerne D. Kulm were informative and much appreciated. Gordon Ness and LaVerne D. Kulm critically reviewed the manuscript. Steven Troseth drafted the illustrations.

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John L. Schwabe elected Chairman of Department Governing Board

At a meeting of the Governing Board of the Department of Geology and Mineral Industries on September 26, John L. Schwabe, Portland, was elected Chairman.

The Board has scheduled its next meeting for November 20 to discuss changes in Oregon's oil and gas rules to regulate the spacing of wells and to determine categories under the Natural Gas Policy Act of 1978. □

Lab fees to increase

A new fee schedule for the analytical services offered by the Oregon Department of Geology and Mineral Industries will become effective January 1, 1980, and will supersede the fee schedule of September 1, 1974. Copies of the new fee schedule will be available upon request.

The Department laboratory provides analytical support for staff work. As provided in ORS 516, it also provides services to the public that are not generally offered by commercial laboratories. Because of the greatly increased demand for the lab services and the remodeling of the State Office Building, results of analyses will be delayed somewhat. The waiting period at this time is about four weeks. □

Correction:

The word "there" should not have appeared in line 2, paragraph 3, column 2, p. 161, in the October issue of *Oregon Geology*. The line should read, "Palagonite and peperites are commonly present, indicating that the basalt was interacting with water. . . ." □

Earthquake engineering conference held at Stanford University

The Second U.S. National Conference on Earthquake Engineering was held August 22-24, 1979, at Stanford University. The conference was sponsored by the Earthquake Engineering Research Institute (EERI) with the cooperation of Stanford University and 11 other professional and governmental organizations, including the American Society of Civil Engineers (ASCE), the Seismological Society of America, and the U.S. Geological Survey.

The conference attracted over 900 registrants, making it the largest earthquake conference ever held, according to its sponsors. The purpose of the conference was to "disseminate information about earthquakes and their effects in order to minimize the disruption, damage and loss of life caused by earthquakes; to stimulate cooperation between engineers and persons from other disciplines in coping with earthquakes; to spread new research and design knowledge to engineers and others; and to summarize current knowledge."

Technical sessions covered risk analysis, industrial facilities, seismology and geology, structural engineering, geotechnical engineering, public policy and economic studies, and lifeline engineering.

Preliminary data from the August 6, 1979, earthquake in central California were presented. This quake, which measured 5.9 on the Richter scale, underscored the fact that peak acceleration alone is an inadequate measure of an earthquake's potential for causing structural damage. Accelerations as high as 0.42 *g* near the epicenter at Hollister and 0.28 *g* in nearby Gilroy occurred, but structural damage was minimal or nonexistent. Inspections of the towns of Gilroy and Hollister showed only small amounts of fallen stucco, minor plaster cracking, and other generally insignificant damage.

Many foreign countries were represented at the conference. In attendance were ten delegates from the People's Republic of China, who presented six talks on the July 28, 1976, Tangshan earthquake. This earthquake had a magnitude of 7.8 and was followed by innumerable aftershocks, some with magnitudes as high as 7.1. Damage was severe, with 80 percent of the industrial facilities and 90 percent of the brick structures in the city destroyed or heavily damaged. An estimated 750,000 people were killed, making this the second worst earthquake in history. Although there was widespread destruction, the earthquake did illustrate that strengthening buildings to withstand seismic shaking could be effective. Those structures that were strengthened with added tie rods and spandrels or whose anchors, connections, and columns had been reinforced because a destructive 1975 earthquake had caused engineers to reconsider seismic potential in the area suffered much slighter damage than did unstrengthened structures.

Proceedings of the conference are available for inspection in the library of the Portland office of the Oregon Department of Geology and Mineral Industries. Conference proceedings are also available by mail from the Earthquake Engineering Research Institute, 2620 Telegraph Ave., Berkeley, California 94704 at a cost of $26 for EERI members and $36 for nonmembers. The cost includes handling, mailing (surface rate; additional charge for airmail delivery), and sales tax. □

James L. Bela, Environmental Geologist
Oregon Department of Geology and
Mineral Industries

New geologic information on Mount Hood released

The Oregon Department of Geology and Mineral Industries announces the release of Open-File Report 0-79-8, *Geothermal Resource Assessment of Mount Hood.* The 273-page report, which presents geologic and geophysical information for the evaluation of the geothermal potential of Mount Hood, was prepared as part of the ongoing geothermal energy research effort by the Department in conjunction with the U.S. Department of Energy, the U.S. Geological Survey, the U.S. Forest Service, and Lawrence Berkeley Laboratory.

Topics discussed in 0-79-8 include:

- Stratigraphy and structure of the Columbia River Basalt Group in the Cascade Range, Oregon: by Marvin H. Beeson and Michael R. Moran, Earth Science Department, Portland State University.
- Geology and geochemistry of Mount Hood Volcano: by Craig M. White, Department of Geology, University of Oregon.
- Gravity measurements in the area of Mount Hood, Oregon: by Richard W. Couch and Michael Gemperle, Geophysics Group, School of Oceanography, Oregon State University.
- Heat flow modeling of the Mount Hood Volcano, Oregon: by David D. Blackwell and John L. Steele, Department of Geological Science, Southern Methodist University.
- Introduction, overview, and conclusions: by Joseph F. Riccio, Geothermal Specialist, Oregon Department of Geology and Mineral Industries.

The report, which is not for sale, is available for inspection in the Department library, Room 555, State Office Building, Portland, Oregon. □

Miners beware

When the Federal Land Policy and Management Act of 1976 (Bureau of Land Management Organic Act) was passed, it changed the recording requirements of the General Mining Law of 1872. Oregon mining laws, however, have not been changed to meet the new Federal requirements. Presently, Oregon does not require a notice of intent to hold a mining claim. Federal law, however, does require such a notice. Therefore, to keep from having your mill site or tunnel site claim become void, you must go beyond that which the State of Oregon requires. The Federal law requires that a notice of intent to hold a mill site or tunnel site be recorded with the local courthouse every year, and a copy of the recorded notice must be filed with the Bureau of Land Management, 729 NE Oregon St., Portland, OR 97208, before December 31 of the same year. The notice of intent to hold the claim can be in letter form and shall contain:

- Name and address of owner or owners;
- The name of the claim or claims, if grouped, and book and page of the record in which the location notice of each such claim is recorded;
- In the case of a mill site, a statement that the claim-related site will continue to be used for mining or milling purposes or that the independent mill site will continue to be used for the purposes of a quartz mill or reduction works, or
- In the case of a tunnel site, a statement that the owner(s) will continue to prosecute work on the tunnel with reasonable diligence for the discovery or development of the vein or lode.

The Federal law recording requirement is based on a calendar year that runs from January 1 to December 31, but Oregon law is based on an assessment year which starts and ends at noon, September 1st. Therefore, for any type of claim (lode, placer, mill, or tunnel) located during September, October, November, or December, a Notice of Intent to Hold Mining Claim needs to be filed in letter form for record during the first calendar year after location in the county in which the mining claim is situated. A copy of the recorded notice must also be filed with the Bureau of Land Management before December 31 of the same year. An affidavit of annual labor must be filed for record in subsequent assessment years. The letter shall contain:

- Name and address of owner or owners;
- Name of the claim or claims, if grouped, and book and page of the record where the location notice of each claim is recorded;
- Statement that annual assessment work is not due;
- Statement that the owner(s) intend to continue development of the claim for the valuable mineral contained therein.

Remember: before December 31 of each year, an affidavit of annual labor or a notice of intent to hold the mining claim must be recorded with the county in which the claim is located. Then a copy of the original which was recorded must be filed with the Bureau of Land Management. □

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National State Land Reclamationists Conference held in Utah

The National Association of State Land Reclamationists held their annual conference in Salt Lake City, Utah, on September 12-14, 1979.

The theme of the meeting was "making reclamation decisions in a stringent performance standards regulatory program." The problems facing the various state reclamation agencies are not so much technical as they are administrative, in light of the very stringent coal mining rules adopted by the U.S. Department of the Interior, Office of Surface Mining.

Almost without exception, the states represented at this meeting expressed their concern over the dilemma of trying to draft a state surface coal mining reclamation program which (1) would meet the requirements of the Office of Surface Mining, and (2) would still be workable in terms of the local and regional conditions. It appears obvious that for a flexible regional application a strong and meaningful state program is needed.

In 1978, the National State Land Reclamationists prepared a resolution calling for a flexible regional concept in the development of surface mining reclamation regulations. This resolution was forwarded to the Office of Surface Mining, and copies were sent to the appropriate mining associations, including the Interstate Mining Compact.

This 1978 resolution was reaffirmed at the 1979 meeting, and letters stating that fact and referencing the 1978 resolution were sent to the Speaker of the House, the Interstate Mining Compact, the Administrator of the Office of Surface Mining, and the President of the United States. The letters also asked for support of the Jackson amendment (S 1403), which essentially accomplishes the aim of the State Land Reclamationists' resolution.

It was the feeling of the group that if Federal surface mining regulations are extended into the areas of noncoal minerals, strong State surface mining regulatory programs in noncoal states are needed for continued State control and regional flexibility. □

Standley L. Ausmus, Administrator
Mined Land Reclamation Division
Oregon Department of Geology
and Mineral Industries

Notice

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Ausmus elected to national office

Standley "Stan" L. Ausmus, Administrator, Mined Land Reclamation Division (MLR), Oregon Department of Geology and Mineral Industries, was elected Vice President of the National Association of State Land Reclamationists (NASLR) for 1980 at their annual meeting in Salt Lake City on September 12-14, 1979.

Prior to coming to the Department in 1974, Ausmus was with the U.S. Bureau of Mines and the General Services Administration. He currently supervises the Department's statewide Mined Land Reclamation program.

Standley L. Ausmus

The MLR law was passed in 1971 by the State Legislature and became effective in July of 1972. The Oregon Department of Geology and Mineral Industries was given the responsibility of administering the program, whose goals are to provide for the protection of the adjacent natural resources and the restoration of the land to a useful and beneficial second use following surface mining.

Initial groundwork, surveys, and contact with the mining industry took place between 1972 and 1974. The first surface permit was issued in the spring of 1974, and Ausmus began his tenure with the Department on May 1, 1974.

The program saw its greatest percentage of growth during the first two years. Since mid-1976, growth has been steady, with a net increase of permitted sites of about 1 percent per month. As of October 1, 1979, there are 691 actively permitted sites, making a total on file of over 2,000 sites which MLR has reviewed.

Currently, MLR is handling this program with one full-time field person, one administrator, and one secretary. The Legislature has authorized and funded another position, and the Division is currently actively recruiting to fill it. □

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COVER PHOTO

Oregon Museum of Science and Industry's Camp Hancock, located in central Oregon's John Day River valley. Article beginning on next page profiles the life of Lon Hancock, the paleontologist after whom Camp Hancock was named. (Photo courtesy OMSI)

Two eastern Oregon quads mapped

The Bullrun Rock and Rastus Mountain 7½-minute quadrangles south of Unity in eastern Oregon are the subjects of two new geologic maps (scale 1:24,000) completed by the Oregon Department of Geology and Mineral Industries with the cooperation of the U.S. Forest Service. These maps can be used to guide mineral exploration, planning, and land management.

Geologic mapping of the Bullrun Rock quadrangle was done by H .C. Brooks and M.L. Ferns; mapping of the Rastus Mountain quadrangle was by Brooks, Ferns, R.W. Nusbaum, and P.M. Kovich.

Important units on the maps include the Jurassic Weatherby Formation and intrusive bodies of probable Cretaceous age. Locally these units have been mineralized and contain small amounts of copper and molybdenum sulfides. The area may have future mining potential, and considerable prospecting is occurring there now.

Blackline prints of the maps, identified as Open-File Reports 0-79-6 (Bullrun Rock) and 0-79-7 (Rastus Mountain), are available now for purchase, at $2.00 per map. They may be bought or ordered by mail from the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201, and from the Baker field office, 2033 First Street, Baker, 97814. Payment must accompany orders of less than $20.00. □

CONTENTS

Alonzo Wesley "Lon" Hancock (1884-1961): a profile

by Viola L. Oberson, 3569 NE Stanton, Portland, Oregon 97212

Mrs. Oberson has been a member and officer of the Geological Society of the Oregon Country (GSOC) for many years. She was the first employee of the Oregon Museum of Science and Industry (OMSI) "and very much part of the successful efforts to bring OMSI to completion" (GSOC Geological News Letter, v. 28, no. 4, April 1962, p. 21). Currently Mrs. Oberson, a freelance writer in Portland, is working on a biography of Lon Hancock, the amateur paleontologist who was the first to discover vertebrate fossils in the Eocene Clarno Formation of north-central Oregon. (Ed.)

Paleontologists the world over know of Lon Hancock's work. Professional men from the universities and museums of the world came to his door to study the fossils he found. He considered himself an amateur, attained no college degrees, and published no scientific papers, but the fossils his persistence enabled him to find have been the subjects of numerous papers, master's theses, and doctoral dissertations. And part of the geologic history of ancient Oregon has had to be rewritten because of his discoveries.

Starting in the early 1930's, Lon Hancock combed the John Day-Clarno hills of north-central Oregon in his spare time, looking for vertebrate fossils in the Eocene Clarno Formation. At times he was accompanied by such scientists as Ralph Chaney, University of California; Chester Arnold, University of Michigan; Chester Stock, California Institute of Technology; Charles Falkenbach, American Museum of Natural History; Donald E. Savage, University of California at Berkeley; and Richard A. Scott and Jack Wolfe, U.S. Geological Survey. Sometimes his search parties consisted of a few friends, and often he went with his wife Berrie, who would drive their car so he could concentrate on looking for outcrops on the hills or in roadcuts. When he retired after 35 years of carrying mail by horse cart and on foot for the U.S. Postal Service in Portland, he believed he had hiked as much on the hills of his beloved Clarno-John Day country as he had walked the sidewalks of Portland.

The Eocene Clarno Formation consists of andesite, mudflows, and tuffaceous sandstones, siltstones, and conglomerates (Oles and Enlows, 1971). It was named by John C. Merriam, who in 1898 led a University of California field party in the exploration of the John Day Basin. At that time, and for many years after, although numerous plant fossils were collected from the Clarno Formation, no vertebrate fossils were found.

Thomas Condon (1910) wrote: "Just why the remains of these same Eocene mammals have not been found in eastern Oregon is one of our unsolved problems. Either the Shoshone region was cut off from the Wasatch region by intervening waters, or if these animals lived in Oregon, their remains may yet be found." Edwin T. Hodge (1941), University of Oregon, wrote: "The only fossils found in the Clarno are plants; no animal remains have been found."

For many years, the search was on to find a bone! In other parts of the world, geologic formations with the same fossil flora had yielded vertebrate fossils as well. Why the John Day Formation, stratigraphically just above the Clarno Formation, should be so rich in vertebrate fossils—and not the Clarno—was a question that challenged both professional and amateur paleontologists and geologists.

On May 28, 1938, Hancock received permission from State Superintendent of Parks S.H. Boardman to dig and collect fossils in John Day Fossil State Park. Together with a friend, Tom Bones, he made the first discoveries of agatized nuts and other fossilized fruits and seeds in what later became known as the Clarno Nut Beds. Since 1942, Tom Bones has devoted his studies entirely to this area, and OMSI recently published a paper on his work (Bones, 1979).

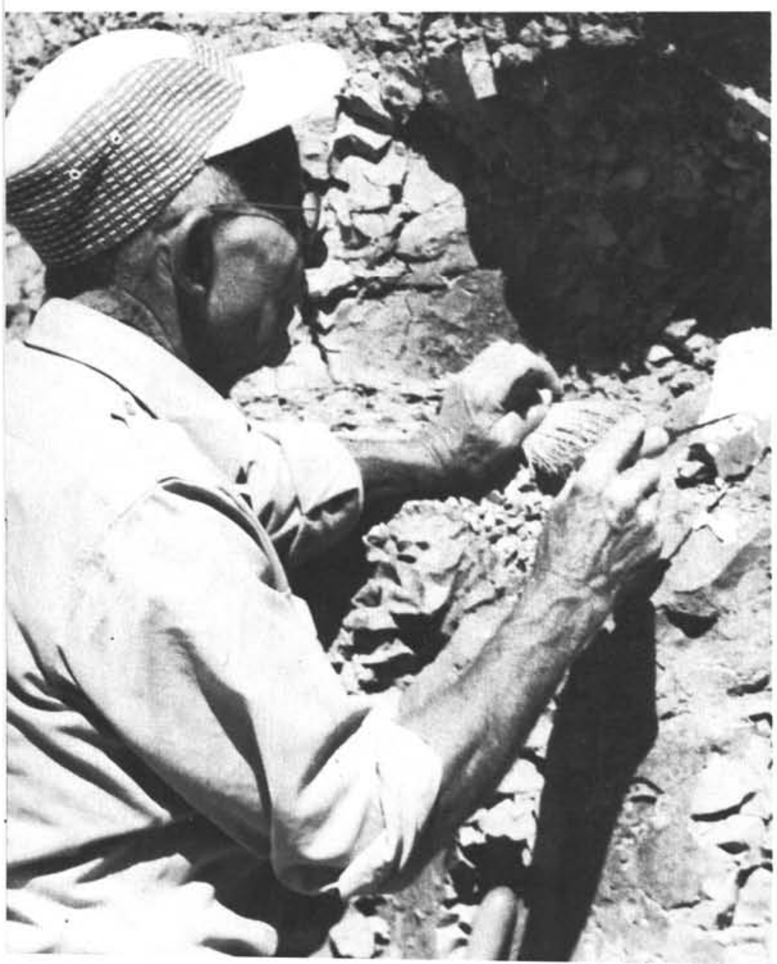
Lon Hancock in his home museum, showing fossil nuts, seeds, and leaves from the Clarno Nut Beds.

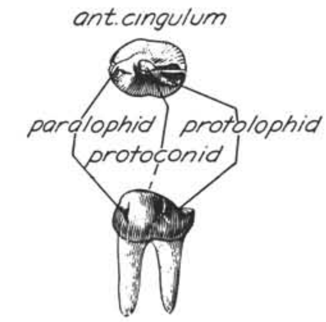
In 1952, a package of seeds and nuts sent from Hancock was examined by Richard A. Scott, then in London, together with Marjorie E.J. Chandler, Curator of the Department of Paleobotany at the British Museum. One pitted seed was identified as a new species of the same genus as a smaller "peach pit" specimen found in the London Clay. Scott wrote to Hancock: "Its relatives lived only in the Malay Peninsula and have never been found either living or fossil in America before—and this large specimen is over twice as large as any previously known species of this genus. If you would be willing to donate this specimen to the University of Michigan Museum, I would like to describe it as a new species, *Paleophytocrene hancockii*, if you don't object to the use of your name." Hancock answered promptly that he would be honored to lend his name to this new species, which was the first of several to carry his name.

Large Clarno Nut Bed collections are now in the Smithsonian Institution in Washington, D.C., and at the Visitors' Center, dedicated August 23, 1978, at the John Day Fossil Beds National Monument, on the former Cant Ranch, Dayville, Oregon. Most of the specimens were collected by Tom Bones.

Hancock continued his search for fossils and in September 1942 made a find that cleared up one aspect of Oregon's ancient history. His consuming dream had

Lon Hancock, working at the Clarno Nut Beds. (Photo courtesy Ed Bushby)





Rhinoceros tooth found by Hancock in the Clarno Formation. Drawing of Hyrachus *sp. tooth by Owen J. Poe (Stirton, 1944, p. 265).*

finally come true. Squeezed tightly against a fossilized walnut was a perfectly formed tooth! Here was proof that animals lived during the Eocene in Oregon. Lon and Berrie hand carried this precious specimen to R.A. Stirton, University of California at Berkeley, who wrote in his 1944 identification monograph:

"The only known fossil mammal tooth from the Clarno Formation of Oregon is a rhinoceros second lower premolar which was discovered near the Clarno Bridge on the east side of the John Day River...in Wheeler County, Oregon. The specimen was found in a tuffaceous matrix bearing crystals of pyroxene and feldspar; many poorly preserved plants were also present. It was found by Mr. A.W. Hancock of Portland, Oregon, in September 1942 and was presented to the University of California Museum of Paleontology for description and preservation.... This, then, is the first specimen recorded outside of the Rocky Mountain area on this continent" (Stirton, 1944).

This discovery of a Clarno *Hyrachyus* or rhinoceros tooth dated the Clarno Formation as middle Eocene (Stirton, 1944) and led to the discovery of the mammal beds.

In April 1954, Al McGuiness directed Hancock to a spot a mile north of the Clarno Nut Beds where he had found some flat "stones" lying loose. Hancock recognized them as bones. He returned to the site five more times with either Murray Miller, Rudolph Erickson, Leo Simon, or Tom Bones, digging many test holes and finally finding some other bones, both small and large, this time in place. From these "new diggings" he later found many specimens that were added to his collection or sent encased in plaster of Paris to the University of Oregon Natural History Museum under the care of the director, J.A. Shotwell.

One of these specimens, a tapir skull, was identified in 1963 and posthumously named for "the late A.W. Hancock, who was the first to discover a fossil mammal in the Clarno Formation" (Radinski, 1963). Radinsky, in his Yale University doctoral dissertation, identified

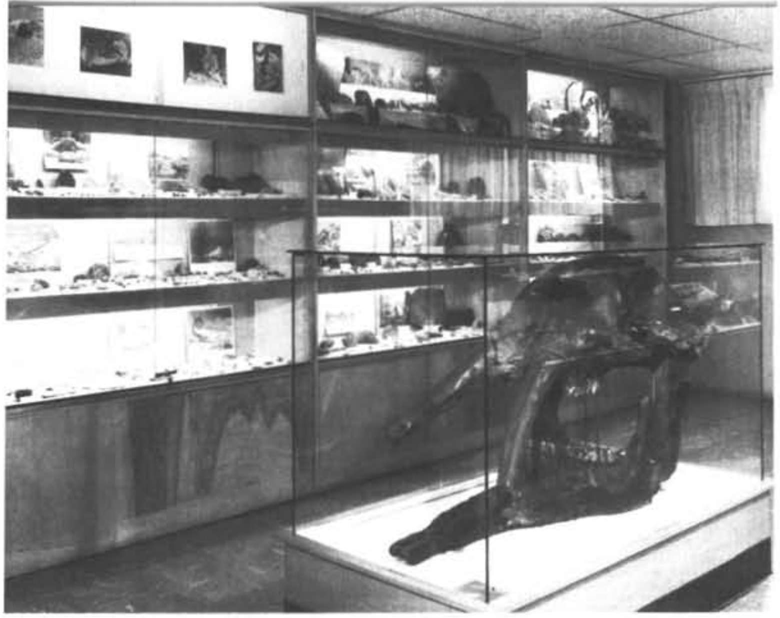
Part of Hancock's home museum. Here over 15,000 children became acquainted with the life of the past.

one of Hancock's finds as the anterior part of a tapir skull with teeth and named it *Colodon? hancockii,* sp. nov. It is expected that many other specimens that Lon collected will receive the name *hancockii* when all of the bones, teeth, skulls, and skeletal parts which he sent to the University of Oregon Natural History Museum or gave to OMSI have been identified. Many of the skulls that he collected are now on loan to the Department of Paleontology of the University of California at Berkeley, where Bruce Hansen is in charge of their care and identification.

Hancock found in the Clarno digs the largest fossil skull yet found west of the Rockies—that of the giant "Thunderbeast" *Brontotherium.* Hancock unearthed rhinos, alligators, tiny camels, great cats, clawed horses, and horses tiny enough to have been carried under his arm or in his pocket. He also found parts of animals that had earlier been found only east of the Rockies and in Asia, among them *Titanotherium, Amynodon, Uintatherium, Hyrachyus, Chalicotherium,* and *Hyaenodon.* As Phil Brogan wrote in the July 8, 1979, *Oregonian*: "Many other mammal finds have been made in the Clarno beds in recent years. They have linked Oregon's Clarno lands with the ancient continent of North America of the early Cenozoic Era."

Lon Hancock was a most generous man. He shared his home museum with classes of grade school children twice a week during the school year. Over 15,000 children, including boy scouts, girl scouts, and campfire girls, and nearly as many high school and college students and adults came to his museum room, which was arranged according to geologic eras and backgrounded by *Life* magazine posters picturing the flora and fauna of each period. His generosity with his lifetime collection of mammal fossils, rocks, minerals, fossil leaves, nuts, and fruits was evidenced by his willingness to have it used forever as a learning tool. His case of fossil skulls and skeletal bones brought the first

Tom Bones (left) and Lon Hancock at work in the Clarno Nut Beds.

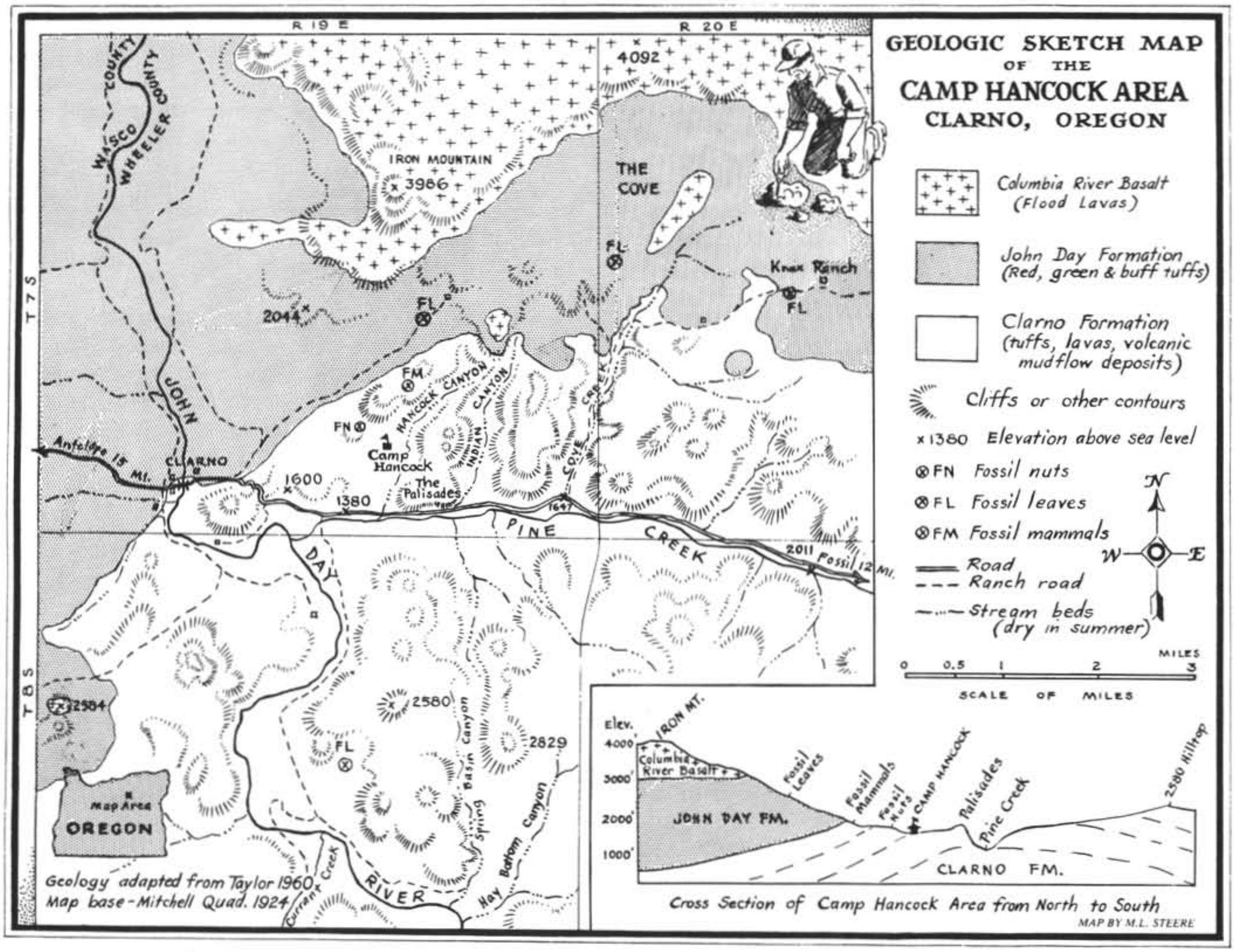


Part of Hancock's fossil collection, as arranged at OMSI by his wife Berrie. (Photo courtesy Delano Photographics)

visitor to the old "Writing Room" in the historic Portland Hotel where OMSI's original office and display room were set up by John C. Stevens and managed by this author. In accordance with Hancock's wishes, his entire home museum collection was given to OMSI after his death.

Lon and Berrie had no children of their own, but their generosity and dedication to youth is marked by their establishment of an outdoor school in Lon's beloved Clarno land. They spent a year of weekends stockpiling rocks away from where the kitchen, dining room, and tents would be placed. Lon drew his plans well for this school whose textbooks he knew he could unfold for all who would come. No other man could hold so many spellbound with the story of the geologic ages as he did on the top of Red Hill with his "sermon on the mount." The spot he chose for the site of his first outdoor school later became known as Camp Hancock. It

Camp Hancock in its early days. (Photo courtesy Ed Bushby)



is now a place name on all Oregon maps and is described by Lewis L. McArthur in his book *Oregon Geographic Names*:

"Camp Hancock, Wheeler County. Camp Hancock is a memorial to Lon W. Hancock, an amateur paleontologist and geologist. Hancock was born in Harrison, Arkansas in 1884. He left school at an early age and spent most of his adult life as a Post Office employee in Portland. He had an abounding interest in fossil hunting and during the 1940s he began taking young boys on outings in the Clarno area. These became more complex and in 1951 Lon and his wife took fourteen boys and ten volunteer staff members for the first formal twelve day summer camp at Camp Hancock under the sponsorship of the Oregon Museum of Science and Industry. Interest grew apace and the early tent camp has grown to a modern, well-equipped facility. Hancock died in 1961 and left his collection of more than 10,000 fossils and artifacts to OMSI" (McArthur, 1974, p. 111-112).

Truly, as is inscribed on Lon's posthumously awarded OMSI trophy, he was "A devoted paleontologist who dedicated his future so that others could learn of the past."

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Biostratigraphy of the Texaco Clark and Wilson No. 6-1 Well, Columbia County, Oregon

by Daniel R. McKeel, Consulting Paleontologist, Route 1, Box 157A, Otis, Oregon 97368

The following report is based on interpretations of Foraminifera at 42 different horizons within the interval from 30 to 8,451 ft. Unprocessed core and ditch samples and some previously picked faunal slides were borrowed from the Oregon Department of Geology and Mineral Industries and from the Department's R.E. Stewart Collection stored at Portland State University.

Essentially three intervals were found to contain age-diagnostic faunas: 575-2,052 ft; 3,282-4,325 ft; and 8,021-8,308 ft. All are interpreted to be equivalent to the Narizian Stage of Mallory (1959). The deepest upper Narizian fauna in this study was found at 4,325 ft. Narizian faunas below 8,000 ft are too sparse to allow determination whether they are upper or lower Narizian in age.

Open marine conditions are indicated by the presence of Radiolaria in all three of the above-mentioned intervals. A regressive sequence is evident in the upper half of the well. Bathyal faunas are present from 4,325 up to 3,282 ft and from 2,040 to 2,052 ft; outer neritic to upper bathyal faunas extend from 1,818 up to 700 ft; and neritic faunas occur from 575 up to 215 ft.

A detailed study (at 30-ft intervals) from 30 to 575 ft may show that some of this section is post-Narizian in age. The two fossiliferous samples (215 and 395 ft) studied here contain Foraminifera, but they are too sparse for age interpretation with any certainty.

Foraminiferal report

Depth (ft)	Stage/Age	Paleoenvironment
30 (ditch)*	Indeterminate	Marine (based on lith only)
215 (ditch)*	Indeterminate	Neritic
395 (ditch)*	Indeterminate	Open marine, near-shore neritic
575 (ditch)*	Narizian (upper Eocene)	Open marine, neritic
700-710 (core)**	Upper Narizian (upper Eocene)	Open marine, outer neritic–upper bathyal
915-925 (core)**	Upper Narizian (upper Eocene)	Open marine, outer neritic–upper bathyal
1,103-1,113 (core)**	Upper Narizian (upper Eocene)	Outer neritic–upper bathyal
1,325-1,335 (core)**	Upper Narizian (upper Eocene)	Open marine, outer neritic–upper bathyal
1,548-1,558 (core)**	Upper Narizian (upper Eocene)	Neritic to upper bathyal
1,568-1,574 (core)**	Upper Narizian (upper Eocene)	Neritic to upper bathyal
1,814-1,818 (core)**	Upper Narizian (upper Eocene)	Open marine, outer neritic–upper bathyal
2,040-2,052 (core)**	Upper Narizian (upper Eocene)	Nearshore bathyal
2,992-3,002 (core)**	Indeterminate	Marine
3,282-3,292 (core)**	Upper Narizian (upper Eocene)	Open marine, near-shore bathyal
3,435-3,510 (2 ditch samples combined)*	Upper Narizian (upper Eocene)	Open marine, near-shore bathyal
3,585 (ditch)*	Upper Narizian (upper Eocene)	Open marine, near-shore bathyal
3,800 (ditch)*	Upper Narizian (upper Eocene)	Open marine, near-shore bathyal
3,870 (ditch)*	Narizian (probably upper Eocene)	Open marine, near-shore bathyal
4,015 (ditch)*	Narizian (probably upper Eocene)	Open marine, near-shore bathyal
4,100 (ditch)*	Narizian (probably upper Eocene)	Open marine, near-shore bathyal
4,325 (ditch)*	Upper Narizian (upper Eocene)	Open marine, near-shore bathyal
4,545 (ditch)*	Indeterminate	Indeterminate
4,740 (ditch)*	Indeterminate	Indeterminate
4,970 (ditch)*	Indeterminate	Indeterminate
5,575 (ditch)*	Indeterminate	Indeterminate
6,115 (ditch)*	Indeterminate	Indeterminate
6,730 (ditch)*	Indeterminate	Indeterminate
7,400 (ditch)*	Indeterminate	Indeterminate
7,545 (ditch)*	Indeterminate	Indeterminate
7,620 (ditch)*	Indeterminate	Indeterminate
7,723 (core)*	Indeterminate	Probably neritic
7,733 (core)*	Tertiary	Probably neritic
7,780 (ditch)*	Indeterminate	Neritic?
8,021 (core)*	Narizian (probably upper Eocene)	Open marine, near-shore neritic
8,030 (core)*	Indeterminate	Neritic to upper bathyal
8,042 (core)*	Indeterminate	Neritic
8,213 (core)*	Indeterminate	Open marine
8,274 (core)*	Narizian (probably upper Eocene)	Open marine
8,308 (core)*	Narizian (probably upper Eocene	Open marine
8,318 (core)*	Indeterminate	Open marine, bathyal
8,325 (core)*	Indeterminate	Open marine, outer neritic–bathyal
8,365 (core)*	Indeterminate	Open marine
8,451 (core)*	Indeterminate	Open marine

* Unprocessed sample.

** Previously picked faunal slide (from the R.E. Stewart collection housed at Portland State University).

REFERENCE CITED

Mallory, V.S., 1959, Lower Tertiary biostratigraphy of the California coast ranges: Tulsa, Oklahoma, American Association of Petroleum Geologists, 416 p. □

Subsurface correlations in the Mist area, Columbia County, Oregon

by Vernon C. Newton, Jr., Petroleum Engineer, Oregon Department of Geology and Mineral Industries

Exploration for oil and gas first began in the Mist area in 1946 when Texaco, Inc., put down its Clark and Wilson No. 6-1 well approximately 1¼ mi southeast of this small community (Figure 1). The project was part of a drive by industry to find new petroleum reserves after the end of World War II. Texaco encountered gas shows in sand of the uppermost Cowlitz Formation in Clark and Wilson No. 6-1, but the sands were found to be saturated with saltwater. Following Texaco's drilling, lands in Columbia County were leased by Superior Oil Company, Standard of California, and Mobil Oil Company over a 25-year period. No new holes, however, were put down until Reichhold Energy Corporation and its partners began exploring the area again in 1975.

After drilling three dry holes north of Mist, Reichhold and partners announced on May 1, 1979, that a commercial gas discovery had been made in its Columbia County No. 1 – Redrill. The field is now undergoing development by Reichhold Energy Corporation, Northwest Natural Gas Company, and Diamond Shamrock Corporation. American Quasar Petroleum Company is drilling south of Mist to establish the southerly extension of the field.

The Texaco Clark and Wilson No. 6-1 well probably penetrated between 100 and 500 ft of rocks of the marine Keasey Formation before reaching Cowlitz-age rocks. The upper section of the Cowlitz Formation in this well is predominantly marine siltstone and mudstone. A silty sandstone body that was encountered between 1,900 and 2,300 ft has potential as a reservoir sand but at this location appears too silty and tight to produce a commercial quantity of gas. The main sand body lies between the depths of 3,000 and 3,600 ft. This sandstone interval appears to have good reservoir potential, based upon interpretation of the electric log and results of porosity and permeability tests performed on surface samples from the area and subsurface samples from two deep Texaco holes drilled in Columbia County (Figures 2 and 3 and Tables 1, 2, and 3). Volcanic rocks predominate between the depths of 4,500 and 7,500 ft in Clark and Wilson No. 6-1. These extrusive rocks consist of submarine lavas, volcanic breccias, and tuffs, with interbeds of Cowlitz-age siltstone, shale, and conglomerate. They were named the Tillamook Volcanic Series by W.C. Warren and others in 1945 and were tentatively assigned a wide age range extending from at least middle Eocene to upper Eocene. The upper portion of the Tillamook Volcanic Series is equivalent to the Goble Volcanics, and both are interbedded with late Eocene marine sediments.

Sandstones in the lower portion of the Cowlitz Formation have potential for producing gas and possibly oil. In formation tests made in the Clark and Wilson No. 6-1 well at 7,880 to 8,000 ft, saltwater flowed to the surface, indicating that the sandstones have fairly good porosity and permeability. Mapping done by the Oregon Department of Geology and Mineral Industries in 1974-75 showed that it would be possible to locate a well updip from the Clark and Wilson No. 6-1. Subse-

Figure 1. Texaco's Clark and Wilson No. 6-1 well, drilled in 1946-47 near Mist. (Photo courtesy Oregon Historical Society)

Table 1. Porosity—permeability of outcrop samples*

Formation	Location	Permeability (millidarcies)	Porosity (percent)	Sample description
Upper Cowlitz	NW¼ sec. 31, T. 4 N., R. 5 W.	66	31.5	Sandstone; fine-grained, silty, micaceous, lithic arkose
Upper Cowlitz	SE¼ sec. 5, T. 4 N., R. 5 W.	206	34.0	Sandstone; very fine-grained, silty, micaceous, lithic arkose
Upper Cowlitz	NE¼ sec. 28, T. 4 N., R. 5 W.	46	30.9	Sandstone; very fine-grained, silty, micaceous, lithic arkose
Upper Cowlitz	NW¼ sec. 23, T. 4 N., R. 5 W.	71	32.0	Sandstone; fine-grained, silty, micaceous, lithic arkose
Upper Cowlitz	NW¼ sec. 23, T. 5 N., R. 6 W.	823	36.2	Sandstone; very fine-grained, silty, lithic arkose

* Source: Newton and Van Atta, 1976, p. 50-51.

Table 2. Texaco—Clark and Wilson No. 6-1
NE¼ sec. 19, T. 6 N., R. 4 W.
Porosity—permeability of upper Eocene sandstone*

Formation	Depth (ft)	Permeability (millidarcies)	Porosity (percent)	Sample description
Upper Cowlitz	2,015	81.1	29.0	Sandstone; micaceous arkose
Upper Cowlitz	2,033	59.7	30.8	Sandstone; micaceous arkose
Upper Cowlitz	3,073	65.0	23.1	Sandstone; micaceous arkose
Upper Cowlitz	3,085	806.1	27.9	Sandstone; micaceous arkose
Upper Cowlitz	3,105	1,302.3	26.2	Sandstone; micaceous arkose
Upper Cowlitz	3,239	398.5	29.4	Sandstone; micaceous arkose
Upper Cowlitz	3,304	499.0	27.1	Sandstone; micaceous arkose
Lower Cowlitz	7,895-7,985	(Too friable—no recovery)		

* Source: Newton and Van Atta, 1976, p. 53-54.

Table 3. Texaco-Benson Clatskanie No. 1
NE¼ sec. 36, T. 7 N., R. 4 W.
Porosity—permeability of upper Eocene sandstone*

Formation	Depth (ft)	Permeability (millidarcies)	Porosity (percent)	Sample description
Upper Cowlitz	2,124	82.0	24.5	Sandstone; arkose
Upper Cowlitz	2,629	106.0	27.2	Sandstone; arkose
Upper Cowlitz	2,648	8,500.0	25.7	Sandstone; arkose
Upper Cowlitz	2,653	722.0	25.1	Sandstone; arkose
Upper Cowlitz	2,699	17.0	27.9	Sandstone; arkose
Upper Cowlitz	2,815	440.0	21.5	Sandstone; arkose
Upper Cowlitz	5,120	0.6	13.7	Sandstone; silty arkose

* Source: Newton and Van Atta, 1976, p. 52.

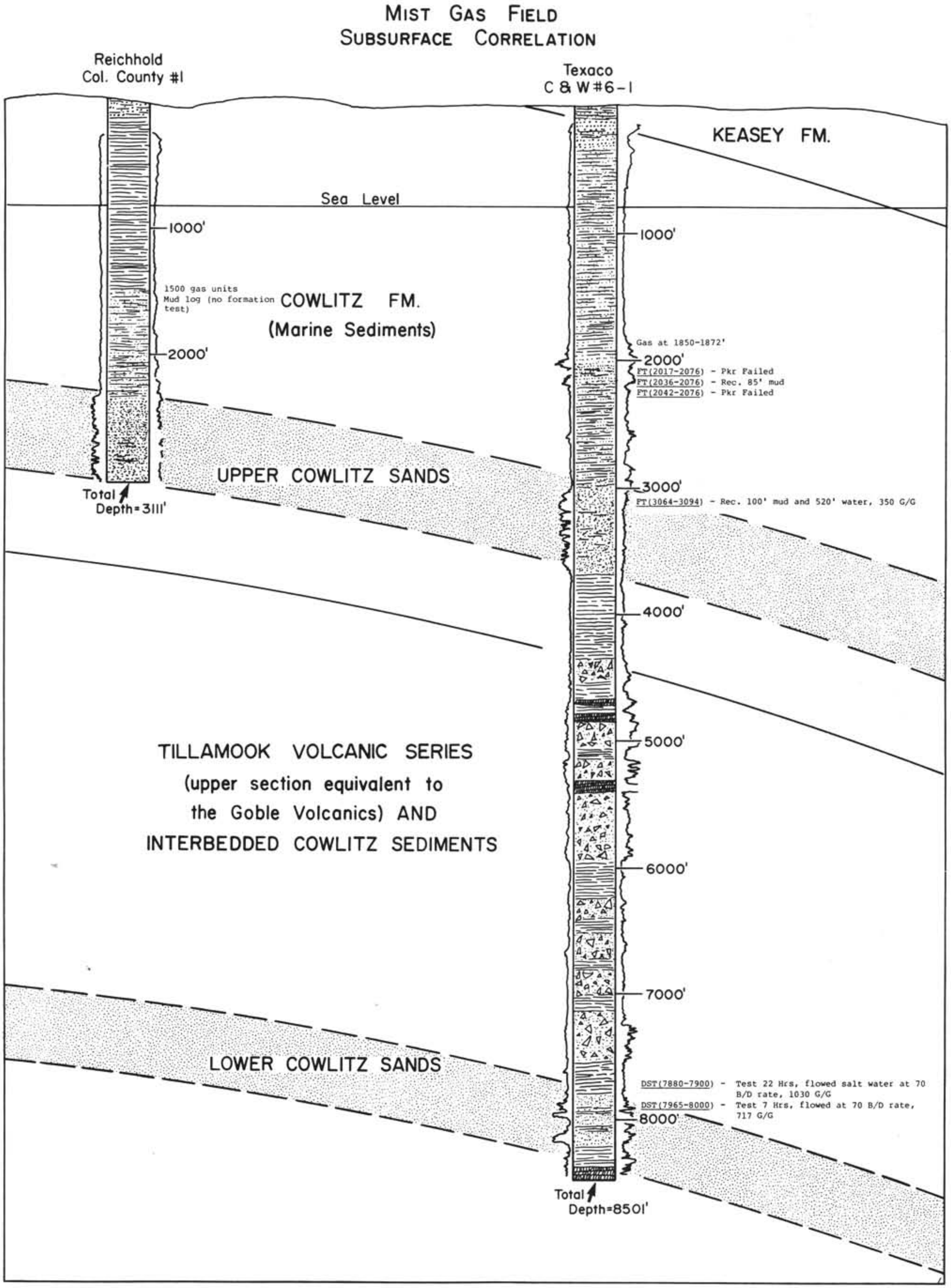


Figure 2. Subsurface correlations at Mist Gas Field.

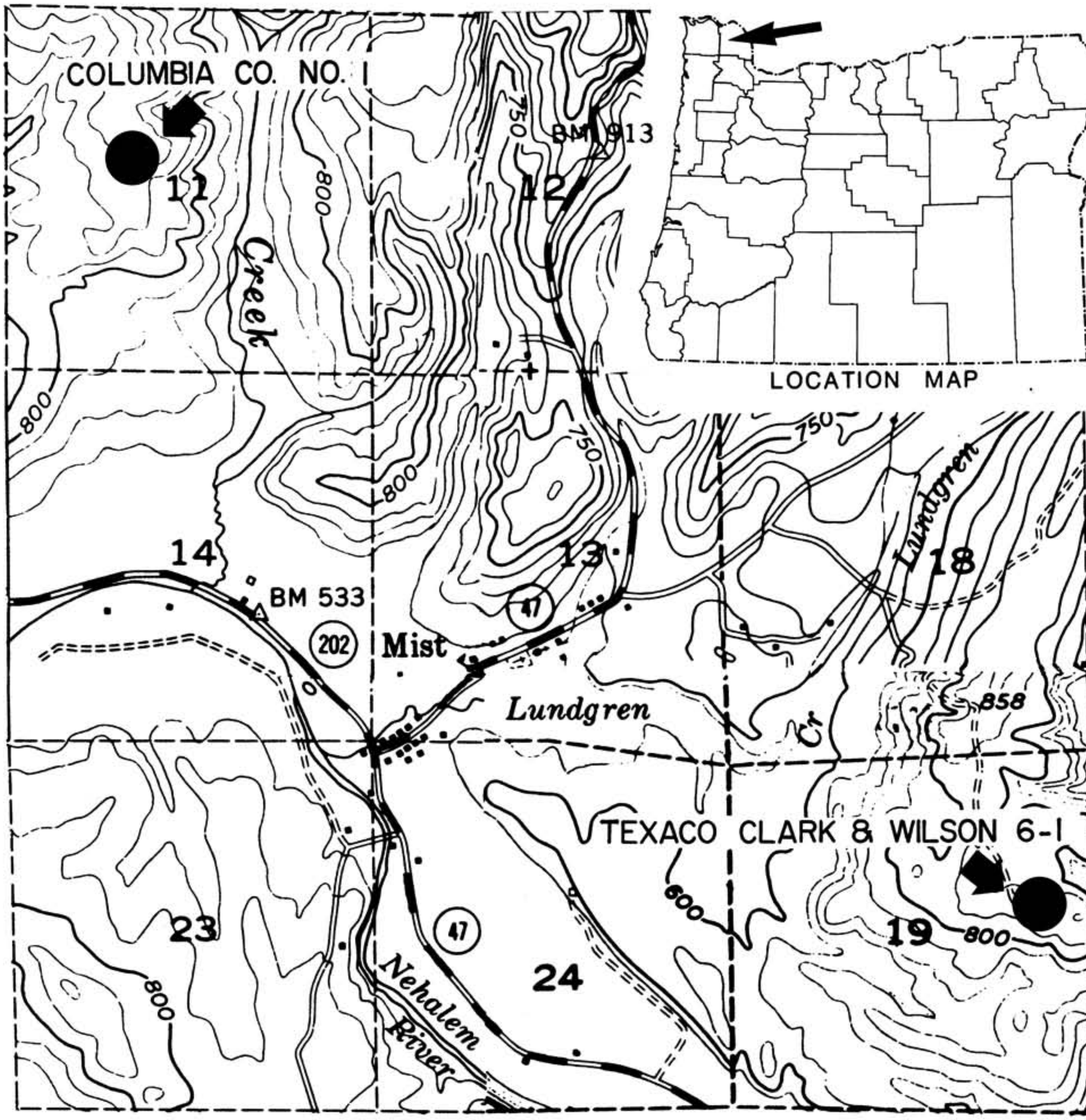


Figure 3. Location of Columbia County No. 1 and Texaco Clark and Wilson No. 6-1 Wells, Columbia County, Oregon.

quent drilling has proven this possibility. With gas production established in the upper Cowlitz sands, it will be very interesting to see whether production can also be found in the lower sands.

Under contract for the Oregon Department of Geology and Mineral Industries, D.R. McKeel, consulting paleontologist, reworked cores and drill cuttings from the Clark and Wilson No. 6-1 well for paleontological information in August 1979. Results of his studies are summarized in this issue of *Oregon Geology* and should be very helpful for anyone conducting investigations in northwestern Oregon. Detailed species lists will be made available in 1980 as part of an open-file report. Subsurface correlations shown in the Department's earlier publications on this area agree substantially with McKeel's findings.

REFERENCES CITED

Newton, V.C., and Van Atta, R.O., 1976, Prospects for natural gas production and underground storage of pipe-line gas in the upper Nehalem River Basin, Columbia-Clatsop Counties, Oregon: Oregon Department of Geology and Mineral Industries Oil and Gas Investigations 5, 56 p.

Warren, W.C., Norbisrath, Hans, and Grivetti, R.M., 1945, Geology of northwest Oregon west of the Willamette River and north of latitude 45°15′: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 42. □

Mist gas discovery guided by Wesley G. Bruer

The discovery of the State's first commercial gas field at Mist, Oregon, is credited to Wesley G. Bruer, consulting geologist for Reichhold Energy Corporation. After drilling seven dry holes in northwestern Oregon, Reichhold and its partners finally achieved success by re-entering the Columbia County No. 1 well and directionally drilling approximately 600 ft away from the surface location.

The Mist Gas Field was born on May 1, 1979, when, five minutes after opening the testing tool valve, gas reached the 2-in. flow line with a roar. At that instant, there was little doubt that the well was a commercial discovery. For Wesley Bruer, who had labored long and maintained faith in the area, and for the companies that had gambled a few million dollars on an idea, there came with the roar of gas a realization that the objective had finally been reached.

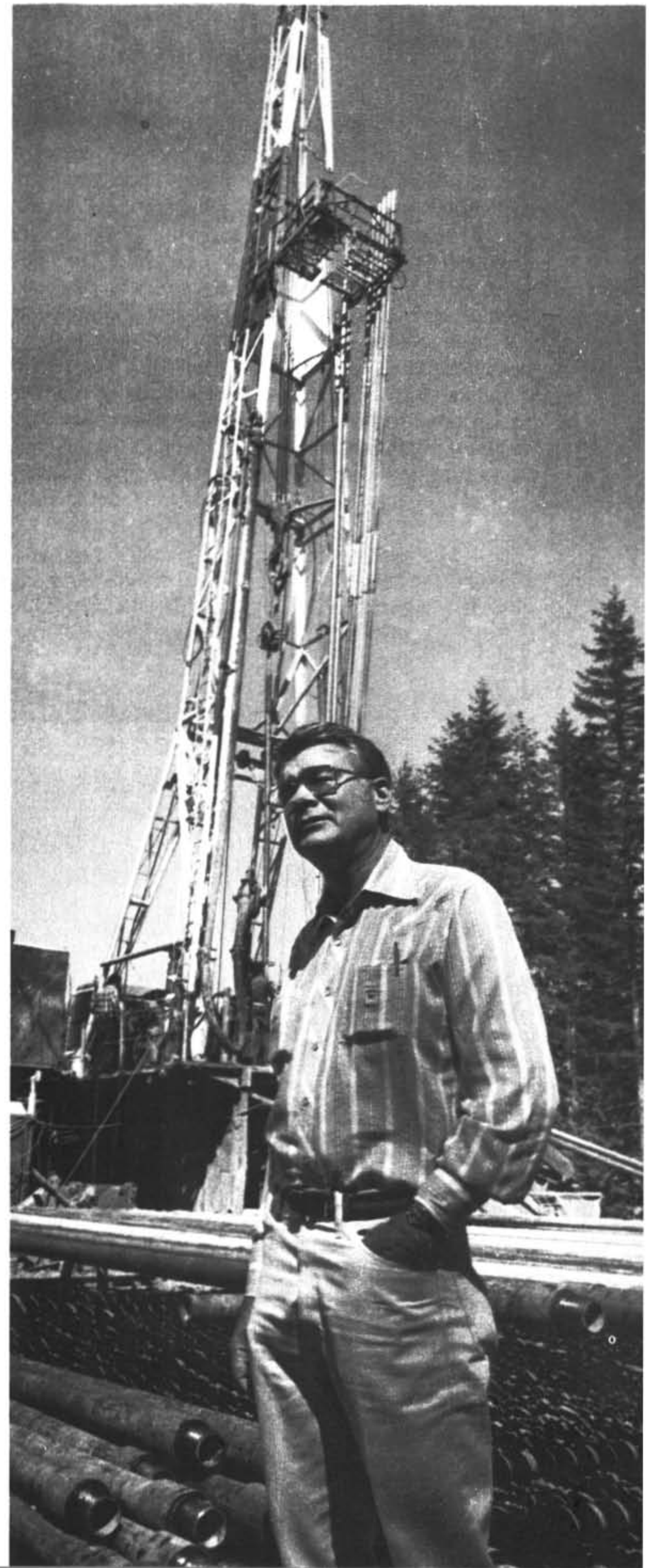
The discovery was mainly an Oregon project, with in-State industries as two of the financial partners: Reichhold Energy, a manufacturer of ammonium nitrate fertilizer, and Northwest Natural Gas Company, a supplier of gas. Wesley Bruer, consultant for Reichhold, was born and raised at St. Helens, Oregon, and was graduated from Oregon State University in 1950.

After graduation, Bruer investigated Oregon's oil and gas potential for Superior Oil Company. Since then, he has held many positions in geology, including California State Geologist from 1969 to 1973 and State Energy Coordinator in California during the early energy crisis years. He has had his own consulting practice for the past several years.

Development drilling by Reichhold is proceeding in the Mist Field, with a total of five producing wells and five dry holes drilled to date. American Quasar Petroleum has moved into the area since the discovery and has drilled two holes south of Mist and another hole south of Clatskanie. All three holes have been plugged. The Department has received applications for permission to drill at an additional twenty-four drill locations from Reichhold Energy Corporation and American Quasar Petroleum Company.

In honor of Bruer's persistent geologic efforts in the Mist area, Oregon's first natural gas pool was named the Bruer Pool during pipeline dedication ceremonies on Nov. 17, 1979.

Total production proved to date is approximately 17 million cu ft per day, an amount equal to 7 percent of Northwest Natural Gas Company's supply in western Oregon. □



Wesley G. Bruer (Photo courtesy Northwest Natural Gas)

Geologists in the Bureau of Land Management, Oregon

by Jack Feuer, Geologist, Oregon State Office, Bureau of Land Management, Portland, Oregon

The Bureau of Land Mangement (BLM) employs 17 geologists in Oregon, most of whom are located in district offices throughout the State. These geologists provide professional input for managing the Federally owned minerals on lands managed by BLM. This is about one-fourth of the land in Oregon (over 15 million acres). BLM also has a limited role concerning the minerals on National Forest land (also about one-fourth of Oregon land).

Until the mid-1960's, BLM geologists (or mining engineers) primarily did mining claim validity examinations for occupancy trespass and mineral patent applications. Other duties included conducting sales of common variety minerals, preparing mineral reports in support of realty and other programs, and determining Federal surface resource rights on mining claims. The role of geologists (and mining engineers) changed considerably with passage of the Federal Land Policy and Management Act of 1976 and other laws that mandated a broader and more active approach to land management than before. In addition to previous duties, BLM geologists are currently involved in energy leasing (oil, gas, and geothermal), land use planning, geologic hazard identification, environmental analyses, and even the wilderness review program.

While BLM geologists seldom do geologic mapping in the traditional sense, they often do original Mineral Resource Inventory (MRI) and mineral resource analysis work for Bureau land use and land management decision-making purposes. These Mineral Resource Inventories and Unit Resource Analyses (URA) are valuable area-wide or planning unit repositories of geologic and mineral-related information. These repositories are open to the public and helpful to those interested in such activities as mineral exploration, rockhounding, geologic mapping, land use planning, and scenic photography.

In its MRI effort, BLM is presently examining younger volcanic flows in eastern Oregon. These include Devil's Garden, Squaw Ridge, and Four Craters in Lake County; Diamond Craters in Harney County; and Jordan Craters, Saddle Butte Lava Field, and Bowden Crater in Malheur County. These MRI examinations will cover both mineral and geologic resources. Geologic resources include any special and distinctive features valuable for education or scientific purposes that land managers should know about. Mineral resources include known resources, mineral occurrences, and mineral potential. Known mineral resources in these areas are mainly slab lava for decorative facing stone, but indicia for other resources and evidence of activity are also inventoried. Known or observed indicia for geothermal resources, no matter how subtle, are especially sought out.

Many of these areas have been given special designations such as established or proposed Research Natural Areas. Some are segregated from mineral entry due to proposed mineral withdrawals. Anyone interested in learning more about these or other areas should contact the local BLM District Office or the State Office where geologists and other resource specialists are available for public assistance. Names and addresses are as follows:

BAKER DISTRICT—523-6391
Gordon Staker, District Manager
P.O. Box 987
Baker, OR 97814
District Mining Engineer—Bob Ciesiel

BURNS DISTRICT—573-2071
L. Christian Vosler, District Manager
74 South Alvord Street
Burns, OR 97720
District Geologist—George Brown

COOS BAY DISTRICT—269-5880
Paul Sanger, District Manager
333 South Fourth Street
Coos Bay, OR 97420
District Geologist—Ben Sprouse

EUGENE DISTRICT—687-6650
Dwight Patton, District Manager
1255 Pearl Street
P. O. Box 10226
Eugene, OR 97401
District Geologists—Ron Wold
Jerry Jones

LAKEVIEW DISTRICT—947-2177
Richard Gerity, District Manager
1000 Ninth Street S.
P. O. Box 151
Lakeview, OR 97630
District Geologist—Dennis Simontacchi

MEDFORD DISTRICT—779-2351
George Francis, District Manager
310 West Sixth Street
Medford, OR 97501
District Geologists—Russ Plume (Detailed to USGS)
Jerry Capps
John Popeck (Detailed from USGS)

PRINEVILLE DISTRICT—447-4115
Paul Arrasmith, District Manager
185 East Fourth Street
P. O. Box 550
Prineville, OR 97754
District Geologist—Dennis Davis

ROSEBURG DISTRICT—672-4491
James Hart, District Manager
777 NW Garden Valley Blvd.
Roseburg, OR 97470
District Geologist—John Kalvels

SALEM DISTRICT—399-5646
Edward Stauber, District Manager
3550 Liberty Road South
P. O. Box 3227
Salem, OR 97302
District Geologist—Jim Warinner

SPOKANE DISTRICT—(509) 456-2570
Roger Burwell, District Manager
Room 551, U.S. Courthouse
West 920 Riverside
Spokane, WA 99201
District Geologist—William Crandell

VALE DISTRICT—473-3144
Fearl Parker, District Manager
365 "A" Street West
P. O. Box 700
Vale, OR 97918
District Geologist—Ed Fivas

OREGON STATE OFFICE—231-6273
729 NE Oregon Street
P. O. Box 2965
Portland, OR 97208

State Office Geologists—	Dave Sinclair	231-6911
	Durga Rimal	231-6976
	Jack Feuer	231-6975
	Dean Delevan	231-6915

□

Archeological information requested

The State Historic Preservation Office, in cooperation with the Anthropology Department of the University of Oregon, maintains a file of archeological and historic sites in Oregon.

Acting State Archeologist Leland Gilsen has asked that any geologists who discover archeological sites during field work report them to his office.

Address any archeological information to: Leland Gilsen, Preservation Archeologist, State Historic Preservation Office, Parks and Recreation Branch, Department of Transportation, 525 Trade Street S.E., Salem, Oregon 97310. □

In memoriam: Fayette W. "Fay" Libbey, 1882-1979

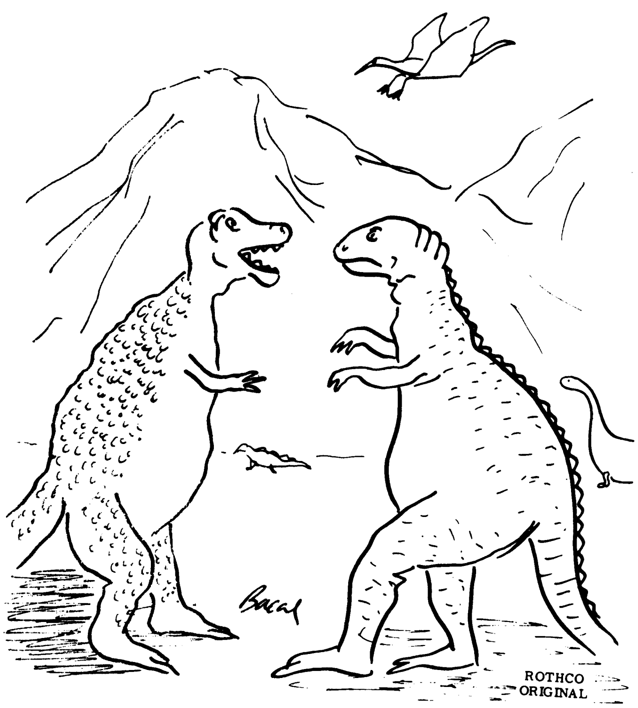
The Oregon Department of Geology and Mineral Industries mourns the death of its second director, "Fay" W. Libbey, who passed away on November 2, 1979.

Fayette Wilmott Libbey was born in Macwahoc, Maine, and grew up in Bangor, Maine. He was graduated from the Massachusetts Institute of Technology in 1906 with a degree in mining engineering. He came to Oregon in 1935 as a geologist with the U.S. Army Corps of Engineers and became the Department's first mining engineer when this agency was created in 1937 by the Oregon Legislature. "Mr. Libbey," as he was usually called by the Department staff, served as director of the agency from 1944 until his retirement in 1954.

It was Libbey's insight and support for exploration that led to the discovery of large areas of ferruginous bauxite in northwestern Oregon. Under his directorship, the Department also investigated and produced publications on coal prospects in the Medford and Coos Bay areas, assessments of potential of the Oregon King Mine in Jefferson County and the Almeda Mine in Josephine County, and the early gold mining activities in Oregon. He received special honors upon his retirement from the Governor of Oregon and the Oregon section of the American Institute of Mining and Metallurgical Engineers. His service to the Department and the State of Oregon covered almost four decades. Visitors to the Department will find a very attractive copper display in the museum and numerous books in the library donated by "our Mr. Libbey." □

NEW OIL AND GAS DRILLING PERMITS

Permit no.	Date issued	Company	Lease name and county	Location
110	9-12-79	American Quasar Petroleum Co.	Well No. 24-11 (Columbia County)	NE¼ NW¼ sec. 24 T. 6 N., R. 5 W.
111	9-28-79	Reichhold Energy Corporation	Crown Zellerbach No. 3 (Columbia County)	SW¼ SE¼ sec. 6 T. 4 N., R. 3 W.
112	9-28-79	Reichhold Energy Corporation	Crown Zellerbach No. 4 (Columbia County)	SE¼ NW¼ sec. 36 T. 5 N., R. 4 W.
113	9-29-79	American Quasar Petroleum Co.	L. Fibre No. 36-41 (Columbia County)	NE¼ NE¼ sec. 36 T. 6 N., R. 5 W.
114	9-29-79	American Quasar Petroleum Co.	L. Fibre No. 31-21 (Columbia County)	NE¼ NW¼ sec. 31 T. 6 N., R. 4 W.
115	10-17-79	Reichhold Energy Corporation	Columbia County No. 12 (Columbia County)	NW¼ NW¼ sec. 14 T. 6 N., R. 5 W.
116	10-24-79	Oregon Natural Gas Development Co.	Crown Zellerbach No. 1 (Tillamook County)	SE¼ NW¼ sec. 13 T. 2 S., R. 10 W.
117	10-24-79	John Miller	John Stump No. 1 (Polk County)	SW¼ NW¼ sec. 26 T. 8 S., R. 5 W.
118	10-23-79	American Quasar Petroleum Co.	Crown Zellerbach No. 29-14 (Columbia County)	SW¼ SW¼ sec. 29 T. 6 N., R. 4 W.



"IS IT MY IMAGINATION, OR HAVE THE WINTERS BEEN GETTING COLDER?"

Juan de Fuca Plate map published by Canadians

A relief map specifically designed as a base for geoscientists working in the Pacific Northwest has recently been published by the Canadian Department of Energy, Mines, and Resources. It is based on the region of the Juan de Fuca Plate and its zone of interaction with North America. The area covered is from the Snake River to the offshore ridge (116°W to 133°W) and from Cape Mendocino to the Queen Charlotte Islands (39°N to 53°N). Sea-floor relief is shown at 200 m intervals and topographic relief at 500 m intervals on a scale of 1:2,000,000.

The map developed in response to a demand for a single projection base which transcended the usual land-sea and Canada-United States borders and provided a focus for studies in a region with a clear tectonic unity. Cultural information (roads, railways, towns, etc.) has been omitted or reduced to a minimum, and the map is available in a three part set. JFP 1 is a full-color version using the International Map of World color scheme; JFP 2 is a black-white contour-only version with all nonrelief information suppressed; JFP 3 is a black-white plotting sheet showing only a degree grid, the coastline, and political boundaries.

The set is available at a cost of $5.00 Canadian, including postage (check or money order payable to the Receiver General for Canada) from "Juan de Fuca Plate Map," Pacific Geoscience Centre, P.O. Box 6000, Sidney, B.C., Canada, V8L 4B2. □

Book review

by Ralph S. Mason, former State Geologist

THE MAGNIFICENT GATEWAY, by John Eliot Allen (1979, Timber Press, 144 pages, photos, maps, and tables). A comprehensive and useful study of the only visible cross-section through the entire length of the Cascade Range.

The author, who is an old hand at teaching geology, has incorporated, as a preface to the geologic story of the Columbia River Gorge, some most helpful information on geologic processes, terms, and map symbols. This material is included to prepare the layman for the detailed discussion that follows on how the Gorge was formed.

Although Allen has written his paperback book primarily for the tourist and interested lay person, he has, through the carefully documented trip logs, assembled a wealth of geologic information of interest to the professional as well. Since travelers through the Gorge move in both directions, two trip logs have been prepared, one covering the area from Portland to The Dalles, along the Oregon side, the other from The Dalles to Vancouver on the Washington side.

No study of the Columbia Gorge can be complete without an account of the catastrophic floods originating from the melting of the ice dams formed during Ice Age time in northern Idaho and western Montana. The cubic miles of water thus suddenly released carved and altered the topography of the Gorge in a matter of a few days.

Also included is information on early Man, trails, weather, and vegetation. Numerous photographs, maps, and charts round out the book. Unfortunately, there is no map of the area devastated by the catastrophic floods. All in all, however, Allen has done an excellent job of explaining how one of the region's prime scenic assets was formed. □

Volcano map available from NOAA

The National Oceanic and Atmospheric Administration has compiled a map locating the volcanoes that have erupted in the last 12,000 years. The 57-by-36 in. map lists some 700 volcanoes and also shows the locations of major earthquakes between 1963 and 1977.

The map is available for $2.50 from NOAA, National Ocean Survey, Distribution Division, C44, Riverdale, Md. 20840. □

DOGAMI adds new staff member: Dennis L. Olmstead

For the past twenty-five years, drilling for oil, gas, and geothermal resources has been conducted on a very limited scale in Oregon. During the last two years, however, the situation has changed dramatically, thereby greatly increasing the regulatory workload for Vern Newton, the Department's only petroleum geologist. On October 22, therefore, the Department added another geologist, Dennis L. Olmstead, to its staff to help with the regulatory work in drilling for oil, gas, and geothermal resources.

Olmstead comes well prepared for his new responsibilities. A graduate of the State University of New York at Oneonta (B.S. in geology, 1969) and of the University of Washington (M.S. in oceanography, 1972), he began his professional career as field geologist for a soil engineering consultant in Sacramento, California. A year later, he joined the California Division of Oil and Gas as energy and mineral resource engineer in the Los Angeles Basin and the Sacramento Valley. This three-year appointment included regulatory responsibilities in testing and inspecting drilling rigs and issuing permits to drill, rework, and abandon wells. For another two years, Olmstead worked for the Division as assistant geothermal officer, regulating geothermal exploratory and development drilling in northern California. He spent the last eight months before joining DOGAMI as geologist for the California Division of Mines and Geology, participating in a low-temperature geothermal assessment program of the Federal and State Departments of Energy.

Although a native of the east coast, Olmstead feels he has come full circle: from his graduate days at the University of Washington via California back to the Northwest. And if he is not outdoors doing his work, you may still find him out there, in the mountains or along the streams, pursuing his hobbies of climbing, skiing, and whitewater boating. □

Index to OREGON GEOLOGY, v. 41, 1979

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DOGAMI REPORTS

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