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COVER PHOTO:

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

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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.

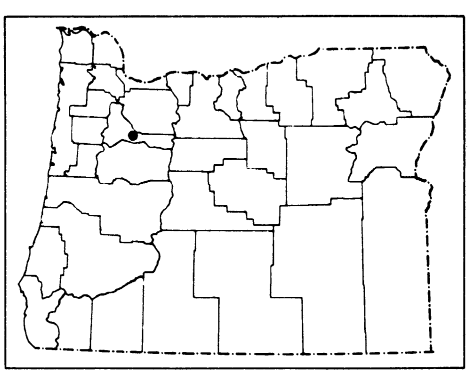
INTRODUCTION

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.

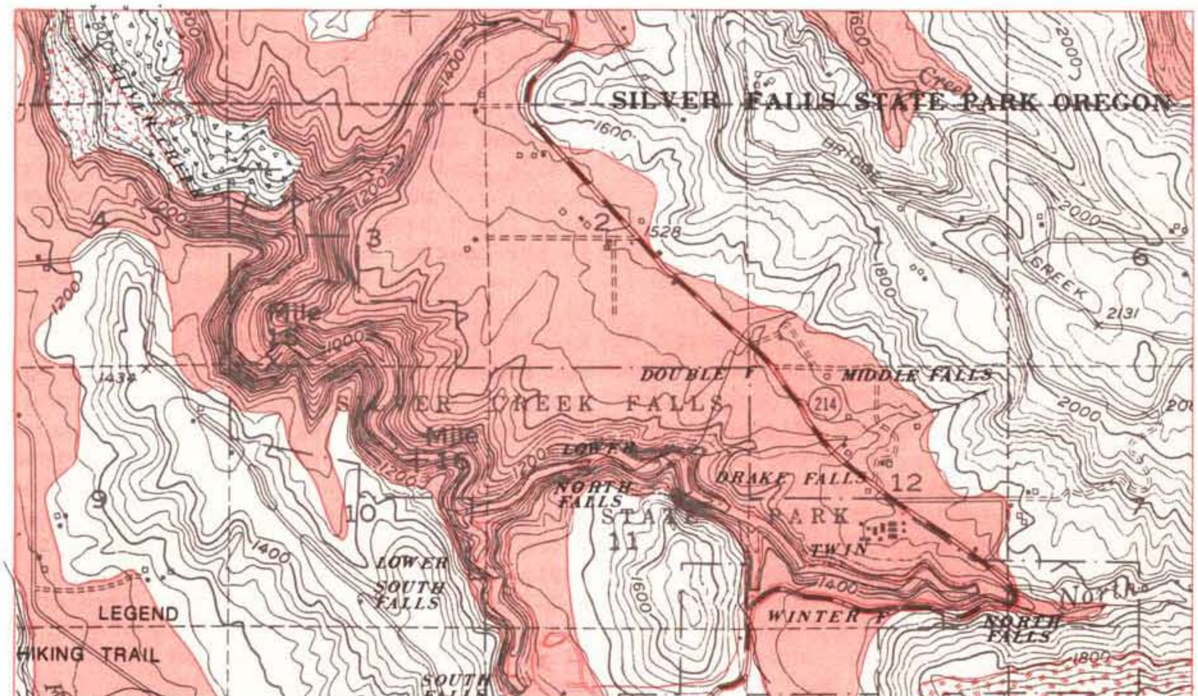
THE PLIOCENE AND PLEISTOCENE

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

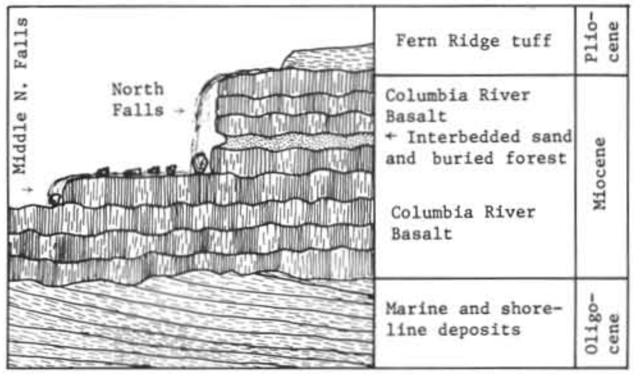
Qls	*Quaternary landslides*
Tsa / Tst	*Sardine Formation* *Tsa, andesite flow rock* *Tst, Fern Ridge tuff*
Tcr	*Columbia River Basalt*
Tm	*Marine sandstone, siltstone, and tuff*
....	*Hiking trail*

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, 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.

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

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

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.

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.

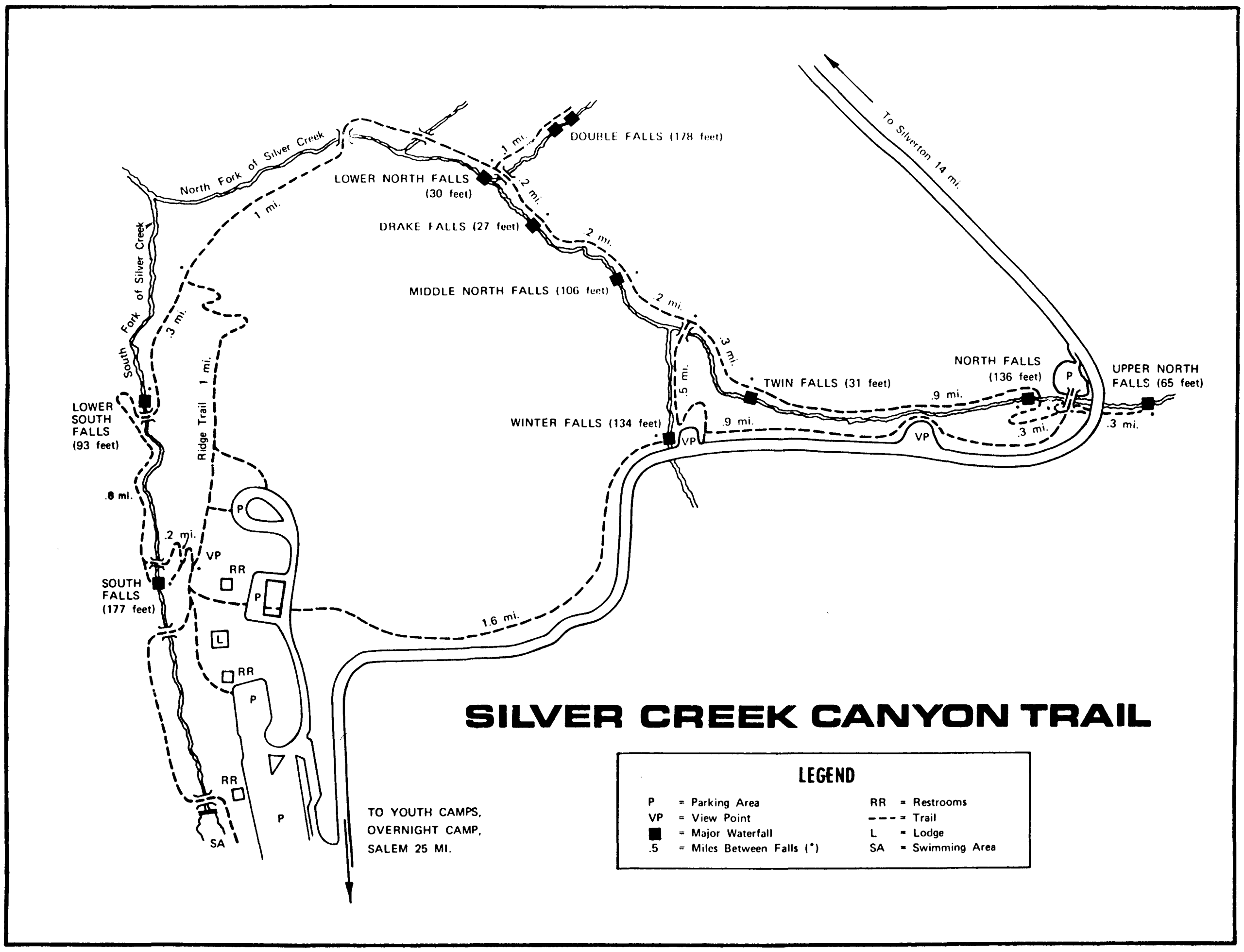
In its early youth, even the main channel of Silver Creek probably dropped over a basalt cliff into a deep gorge on its way to the Willamette River. Those falls gradually receded, cutting back upstream through the lava and finally branching into the North and South Forks of Silver Creek. As the falls 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:

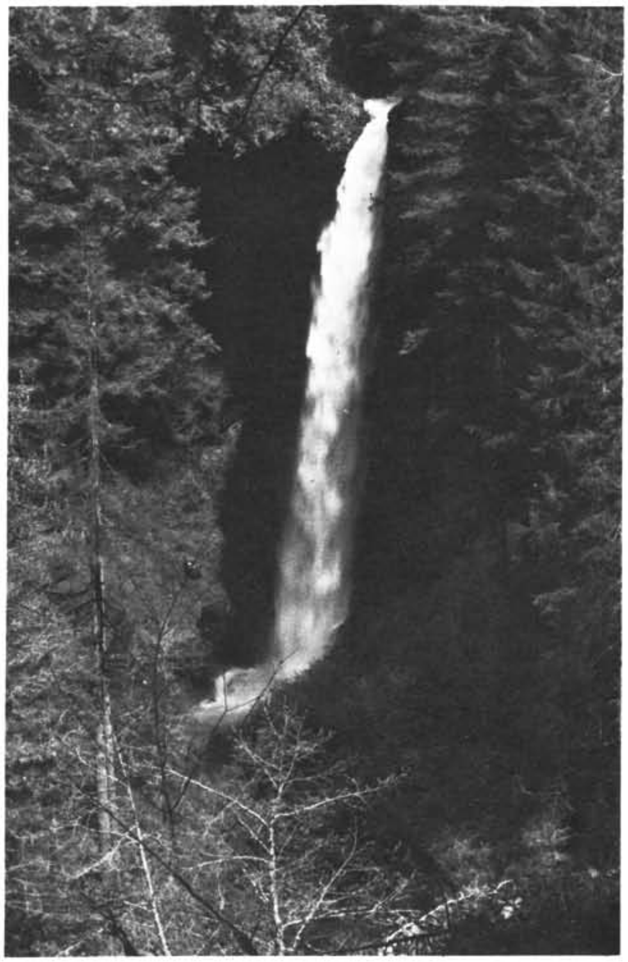
Heights of falls in Silver Falls State Park		
Location	Name of falls	Height (ft)
Above junction of South and North Forks	North	136
	Upper North	65
	Twin	31
	Winter	134
	Middle North	106
	Drake	27
	Double	178
	Lower North	30
	Lower South	193
	South	177
Below junction of South and North Forks	Crag	12
	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 $2x10^5$ 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).

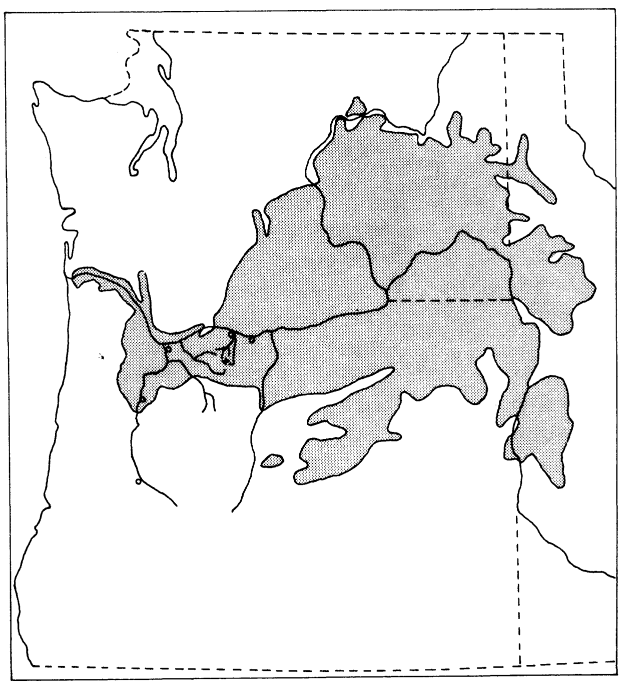


Figure 1. Distribution of Columbia River Basalt Group in Oregon, Washington, and Idaho. (After Waters, 1961)

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						R_2
			Picture Gorge Basalt				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.

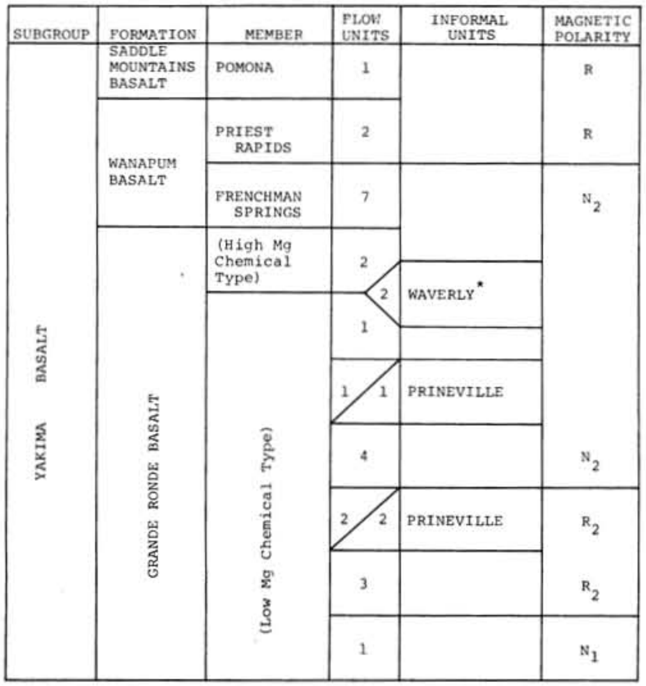
In western Oregon, the Columbia River Basalt Group comprises approximately 21 basalt flows which may be divided into three formations of the Yakima Basalt Subgroup (Figure 3). Distinctive characteristics of each member and of other informal subdivisions are given in Figure 4. These units are tentatively 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



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

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

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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