

**Geologic Field Guide  
to the Columbia River Basalt,  
Northern Idaho  
and Southeastern  
Washington**

John H. Bush  
W. Patrick Seward

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First Edition, September 1992  
ISBN 1-55765-105-1

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## PREFACE

The Columbia River Basalt Group extends over parts of northern Idaho, eastern Washington, and northeastern Oregon. The 6- to 17-million-year-old basalts have been studied in detail for the past two decades. Because of this rigorous work, geologists today can identify and place individual flows within a stratigraphic framework. The current understanding of this geologic province is the result of research programs conducted by many different groups: various universities, the U.S. Geological Survey, state geological surveys, public and private utilities, and the U.S. Department of Energy (DOE). Many of these programs were directly or indirectly supported by the DOE in its effort to assess the suitability of individual flows in the Columbia River Basalt Group as a site for a high-level nuclear waste repository.

This field guide utilizes the same basic stratigraphic framework followed by modern researchers. The road logs are written so that a layperson or beginning student as well as the professional geologist can follow the stratigraphic nomenclature and benefit from the information given. Most geologic features are described in general terms, yet the proper geologic and stratigraphic terminology is always used. For those interested, a thorough reference list provides sources of additional information about the basalt.

The area covered by this field guide—that area served by the Moscow-Pullman/Lewiston-Clarkston communities—contains excellent exposures of Columbia River basalt flows. The road logs herein provide explanations of many of these. The trips are designed for one-day excursions. We recommend the user take the road log to the Snake, Clearwater, and Potlatch rivers first, because it introduces the basic stratigraphic framework of the other trips.

Our work on the field guide profited from the helpful comments of Roy M. Breckenridge. Linda L. Hayden and Mark D. McFadden thoughtfully assisted with the field checking of mileage and geologic features. William C. Rember was a constant source of valuable field information. Bill's unending interest and wide knowledge of local geology and, in particular, that of the Columbia River Basalt Group provided much-appreciated encouragement to complete this book.

# Geologic Field Guide to the Columbia River Basalt, Northern Idaho and Southeastern Washington

By

John H. Bush<sup>1</sup> and W. Patrick Seward<sup>1</sup>

## INTRODUCTION

### COLUMBIA RIVER BASALT GROUP

The Columbia River Basalt Group erupted from fissures during an 11-million-year period of the Miocene (6 million to 17 million years ago). The bulk of the basalt was erupted in the first 1.5 million years (Baksi, 1989) over a 163,700 square kilometer area (Tolan and others, 1989) that included most of eastern Washington, much of northern Oregon, and significant parts of west-central Idaho (Figures 1 and 2). The accessibility of the Columbia River basalt in this broad area makes it amenable to detailed stratigraphic, chemical, magnetic, and petrographic studies.

Most flows of the Columbia River Basalt Group may be identified by their chemical composition. It is now techni-

cally and economically feasible for geologists to have their rock samples analyzed in the field as they map. Furthermore, a fluxgate magnetometer permits the magnetic polarity for each flow also to be determined in the field. Together with field mapping and microscope petrography, the new techniques of rapid analysis and magnetic polarity have enabled scientists to establish a detailed stratigraphic succession for the Columbia River Basalt Group (Figure 3). Based on the stratigraphy, it has been possible to clarify the physical and chemical evolution of the basalt magma, to correlate individual flows with their feeder dikes, and to reconstruct the magnitude of the eruptions. The end of this section on Columbia River basalt contains detailed descriptions of individual flows, members, and formations in the Moscow-Pullman area.

The maximum exposed thickness of the Columbia River basalt is 1,500 meters, but basaltic rocks have been reported from drill cores as deep as 3,000 meters near the center of the plateau (Hooper, 1982). The total thickness

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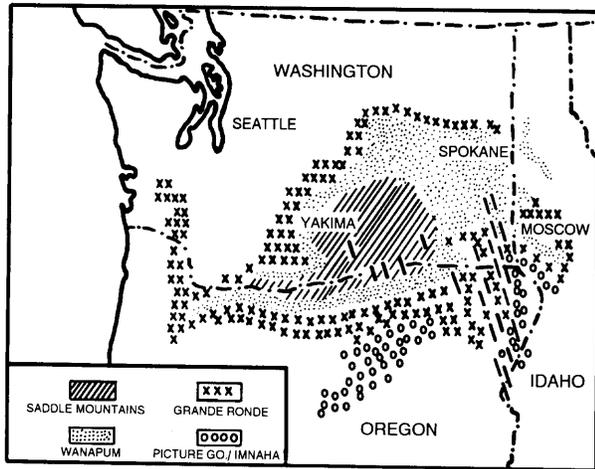


Figure 1. Generalized distribution of Columbia River Basalt Group (Saddle Mountains, Wanapum, Grande Ronde, Picture Gorge, Imnaha). Solid northwest-striking lines indicate the locations of abundant vents.

of the basalt, based on estimates of the greatest known thickness for each formation, is more than 2,500 meters. The Columbia River basalt fills a shallow basin; it is thickest at the center (Pasco Basin) and thins toward the margin. Calculations indicate a total basalt volume of more than 148,600 cubic kilometers. The number of flows identified on the plateau will ultimately be between 120 and 150 (Hooper, 1982). Thicknesses for individual flows are as much as 122 meters and average 15 to 30 meters. Their areal extent ranges from small spatter cones at source vents to major flows that cover a significant part of the Columbia Plateau with volumes as large as 700 cubic kilometers. The flows were erupted from north-northwest to south-southeast fissures concentrated in the southeastern part of the plateau where dikes cut through older lava flows and the surrounding prebasaltic rocks (Swanson and others, 1975).

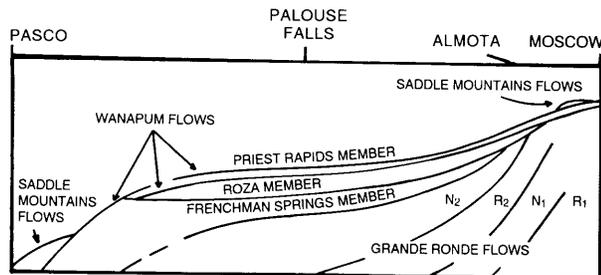


Figure 2. Generalized east-west cross-section illustrating stratigraphic relations between formations and members of the Columbia River Basalt Group (modified from Swanson, 1976).

Near Moscow and Pullman most basalt outcrops are the Priest Rapids Member of the Wanapum Formation. The contact between the Wanapum and underlying Grande Ronde Formation has been mapped along Paradise Creek just west of Pullman (Hooper and Webster,

1982). This contact has also been identified by Brown (1976) in a test well between Moscow and Pullman at a depth of 30 meters.

Outcrops of the Imnaha, Grande Ronde, Wanapum, and Saddle Mountains Formations are all present in the Lewiston-Clarkston area. Dike and vent materials are visible at numerous locations in northern Idaho and southeastern Washington.

PHYSICAL CHARACTERISTICS OF BASALT FLOWS

Basalt flows of the Grande Ronde, Wanapum, and Saddle Mountains Formations range in thickness from less than 30 centimeters to more than 100 meters for an average thickness of 30 to 40 meters. The flows record ponding in valleys, in structurally controlled basins that developed during volcanism, and in narrow canyons eroded into older flows. The latter intracanyon flows are common only in the Saddle Mountains Basalt. Even the thinner flows generally show evidence of ponding based on the columnar-jointed features exhibited by the basalt. Columnar joints apparently form only under static cooling conditions.

	FORMATION	MEMBER	MAGNETIC POLARITY	K/Ar DATE (M.Y.)	
COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	LOWER MONUMENTAL	N	6	
		ICE HARBOR	N <sub>1</sub> R	8.5	
		BUFORD	R		
		ELEPHANT MOUNTAIN	N <sub>1</sub> T		
		POMONA	R	12	
		ESQUATZEL	N		
		WEISSENFELS RIDGE	N		
		ASOTIN	N	13	
		WILLOW CREEK	N		
		UMATILLA	N		
		WANAPUM BASALT	PRIEST RAPIDS	R <sub>3</sub>	14.5
			ROZA	T <sub>1</sub> R <sub>3</sub>	
		GRANDE RONDE BASALT	FRENCHMAN SPRINGS	N <sub>2</sub>	15.3
	ECKLER		N <sub>2</sub>	15.5	
	PICTURE GORGE BASALT		R <sub>2</sub>		
			N <sub>1</sub>		
	IMNAHA BASALT		R <sub>1</sub>	16.5	
		T			
		N <sub>0</sub>	17.5		
		R <sub>0?</sub>			

Figure 3. Generalized stratigraphic terminology of the Columbia River Basalt Group. N=normal magnetic polarity, T=transitional magnetic polarity, R=reverse magnetic polarity. Data are from numerous sources but are primarily modified from Swanson and others (1979), Hooper (1982), and Reidel and Fecht (1987).

Flows that cooled under static conditions contracted and developed a characteristic jointing habit, as shown in

Figure 4. The terms "colonnade" and "entablature" were borrowed from classical architectural usage by Tomkeiff (1940). Colonnade refers to the larger columns that compose the basal part of the flow. Entablature refers to the smaller columns that compose the upper parts of the flow. Columns in the colonnade range from 30 centimeters to 5 meters in diameter, averaging about 1 meter, and can be as long as 75 meters, although they average 15 to 30 meters in length. Most columns are straight, but curved ones are common in places.

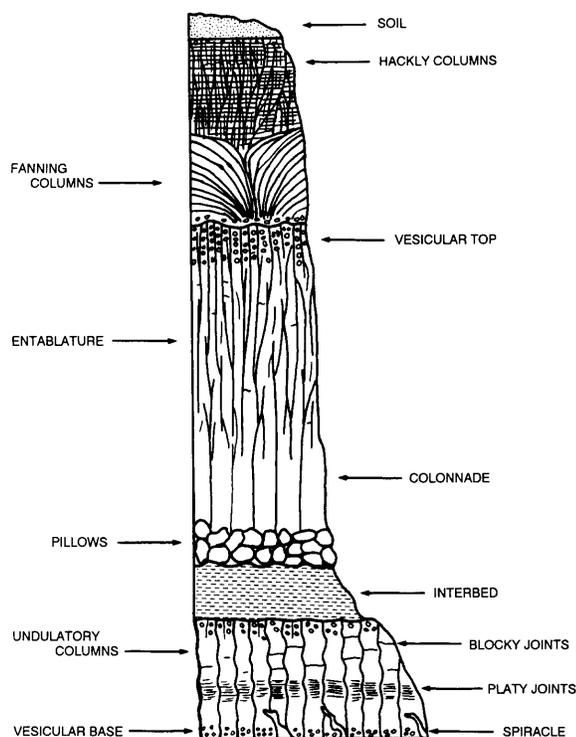


Figure 4. Physical characteristics of Columbia River basalt flows.

The colonnade-entablature contact may be sharp, and the change generally occurs within 1 meter. The contact is traceable in some areas for several kilometers before other complexities obscure it. The glass content of the groundmass increases abruptly from the colonnade to the entablature for unknown reasons (Long, 1978). The entablature consists of columns of smaller diameter, generally less than 1 meter, and of less uniform orientation than those in the colonnade. Columns in many entablatures are bundled into fans, synforms, antiforms, or other unusually shaped arrangements. Most columns in an entablature are highly segmented by irregular cross joints, so that the columns can be readily broken into fist-size pieces. The entablature generally constitutes the major part of the flow, but in places it may be absent with the colonnade then making up the entire flow. The upper part of the entablature is scoriaceous and may merge into a zone of short, wide, poorly defined columns that some workers call the upper

colonnade. A rubbly, clinkery zone occurs above the entablature of many flows. Some flows have a tiered appearance defined principally by alternating zones of vesicular and relatively nonvesicular rock rather than by joints. The vesicular zones are believed to have been formed by postemplacement migration, coalescence, and entrapment of aqueous vapor bubbles (McMillan and others, 1989).

The upper surface of a flow is rarely exposed in plan view. Where seen, the surface is rather flat, smooth, filamented, and locally ropy. The surface of a flow with a rubbly zone is rough, has a relief of as much as 6 meters, and otherwise appears unlike typical surfaces of ponded flows.

Many flows entered water and formed pillows. Studies have demonstrated that pillows are the subaqueous equivalent of pahoehoe toes (Jones, 1968; Moore, 1975). The glass formed by chilling in water decomposes to a yellow mineral (palagonite) diagnostic of pillow lavas. Pillowed flows are more common near the margin of the Columbia River Plateau where flows ponded the rivers draining from adjacent highlands.

Criteria for defining flow directions in basalt flows include inclined pipe vesicles, which plunge upcurrent, and bent spiracles formed by steam blasts beneath a flow, which tail out down current. Flow directional data for basalt must be interpreted in the same way as those for current-produced structures in sedimentary rocks.

## DESCRIPTIONS OF INDIVIDUAL FLOWS AND MEMBERS

### INTRODUCTION

The Columbia River Basalt Group has been subdivided into a large number of flows, members, and formations (Swanson and others, 1979). The term "flow" is used for individual cooling units. The term "member" is defined as a flow or group of flows that can be positively characterized and distinguished from all others by unique physical and chemical properties. These criteria include stratigraphic position, petrographic assemblage, magnetic properties, and chemical composition. Two or more members with identical chemical compositions, regardless of stratigraphic position, may be referred to as the same "chemical type" (Wright and others, 1973).

From the base upward, the Columbia River Basalt Group in the Moscow-Pullman-Lewiston area is subdivided into the Imnaha, Grande Ronde, Wanapum, and Saddle Mountains Formations. The following discussion briefly describes these formations and significant members.

## SADDLE MOUNTAINS BASALT

### Lower Monumental Member

The Lower Monumental Member is a dense aphyric flow that partly filled the canyon of the ancestral Snake River. It occurs as small isolated remnants at or near the level of the present Snake and Clearwater rivers. The remnants extend from the Lewiston basin (Hooper and others, 1985) to at least as far west as Devils Canyon in southeastern Washington (Swanson and others, 1980). The Lower Monumental Member is the youngest known flow of the Columbia River Basalt Group, dated at 6.0 m.y. (McKee and others, 1977). The basalt has normal paleomagnetic polarity (Choiniere and Swanson, 1979). Microphenocrysts of plagioclase, clinopyroxene, and olivine are present in an opaque glass matrix.

### Elephant Mountain Member

The Elephant Mountain Member is a moderately dense, dark gray, aphyric, tiered flow that crops out as remnants of intercanion flows along the ancestral Snake River canyon in the Lewiston basin. In hand specimen, laths of plagioclase and smaller grains of olivine and clinopyroxene are set in areas of dark gray glass. The member is described as having both transitional and normal magnetic polarity (Choiniere and Swanson, 1979) and has been dated at 10.5 m.y. (McKee and others, 1977).

### Pomona Member

The Pomona Member is a medium-grained, gray basalt with rare phenocrysts that crop out in deep (125 meters) preexisting intercanions in the Lewiston area. The source was presumably east or southeast of Lewiston from where lava flowed down the ancestral Snake (Swanson and others, 1980). Where thick sequences are preserved, they are tiered and include a unit of volcaniclastic material of tephra and obsidian. The basalt has reversed magnetic polarity (Choiniere and Swanson, 1979) and has been dated at about 12 m.y. (McKee and others, 1977).

### Wilbur Creek Member

The Wilbur Creek Member is a moderately dense, dark gray aphyric flow that forms a well-exposed unit at the top of the Lewiston grade and along the north side of the Lewiston structure. It forms part of the Uniontown flows, described by Swanson and others (1975), which have an elongate northwest-trending outcrop pattern north of the Snake River and south of Pullman. It also is present over much of the Lewiston basin (Hooper and others, 1985) and has normal polarity (Swanson and others, 1975).

## WANAPUM BASALT

### Priest Rapids Member

The Priest Rapids Member is a coarse-grained flow with plagioclase and olivine phenocrysts. The member occurs as an extensive flow or as flows of relatively uniform thickness over much of the plateau, but is thicker in the Lewiston basin than it is in the Moscow area (Hooper and others, 1985). Major feeder dikes occur in northern Idaho (Camp, 1981). These dikes presumably fed the flows, which moved westward into the central Columbia Plateau as sheetfloods (Swanson and others, 1980). In the eastern part of the plateau this flow overlies a dark brown, well-developed saprolite. The flows have reversed magnetic polarity (Swanson and others, 1979).

### Roza Member

The Roza Member is a consistently plagioclase phyric basalt. The phenocrysts are independent (rarely clotted), are evenly distributed throughout the flow, and average 1 centimeter across. The member is not present in Moscow or Pullman, but from Colfax westward it is easily traced across the plateau. The member has transitional to reversed polarity (Choiniere and Swanson, 1979).

### Frenchman Springs Member

The Frenchman Springs Member is generally a plagioclase phyric basalt. The phenocrysts are irregularly distributed and are mostly found in cumulo-phyric masses. The member progressively thickens westward from its eastern exposures, which consist of one flow, to areas in the central part of the basin where it consists of several flows. The Frenchman Springs is not present in the Lewiston-Moscow-Pullman area. The member has normal magnetic polarity (Rietman, 1966).

## GRANDE RONDE BASALT

The Grande Ronde Basalt is a thick sequence of flows that occur over much of the Columbia River Plateau. The flows are chiefly aphyric, fine grained, and petrographically indistinct. Single flows range in thickness from less than 1 meter to more than 50 meters and cover several tens to several hundreds of square kilometers. Total thickness reaches over 1,000 meters in places. The member has been divided into four units (Hooper and others, 1985) on primarily magnetic differences and has been dated between 15.6 and 17.0 m.y. (Reidel and others, 1989). From the base upward these units are referred to as N<sub>1</sub>, R<sub>1</sub>, N<sub>2</sub>, and R<sub>2</sub>. The Grande Ronde Basalt has a narrow range of chemical compositions and relatively uniform lithology. Reidel and others (1989) used chemical compositions with paleomagnetic polarity, lithology, and stratigraphic position to subdivide the member. They were able to split the

four magnetostratigraphic units into seventeen informal units that can be mapped and recognized across the Columbia Plateau.

### IMNAHA BASALT

The flows of the Innaha Basalt conformably underlie the Grande Ronde Basalt. Generally, they are medium to coarse grained and plagioclase-phyric with phenocrysts between 0.5 and 2.5 centimeters in length. Exposures are characterized by extensive grusy weathering. Most flows have normal magnetic polarity. Since these flows were the first to fill in the prebasalt topography, they vary widely in thickness.

### MIOCENE PLANT FOSSILS

The presence of Miocene fossil plants in sediments interbedded with the Columbia River basalt have been known for many decades (Knowlton, 1926). Numerous sites have been reported, primarily around the edge of the Columbia River Plateau in Idaho, Washington, and Oregon. The road log to the Clarkia fossil area in this field guide focuses on sites near Clarkia, Idaho, where exposures of richly fossiliferous, finely laminated lacustrine deposits have been studied by Smiley and Rember (1979). The sediments examined on the Clarkia trip are probably from a lake formed by the damming of the St. Maries River with Columbia River basalt (Smiley and Rember, 1979). The prebasalt St. Maries River had estab-

lished a drainage in Precambrian- and Cretaceous-aged metamorphic and intrusive rocks. Lake sediments then filled in most of the steep-sided drainages, resulting in the flat valley floor still evident in the Clarkia area.

Plant megafossils are preserved so well in places that the leaves are complete cellular compressions and can be lifted intact from bedding surfaces for microscopic study. Researchers have recently discovered fossilized deoxyribonucleic acid (DNA) preserved in some of the leaves. More than a hundred species of ligneous (woody) plants are known to occur as fossils in the Clarkia Lake deposits (Smiley and Rember, 1979). The plant cover that formed around Miocene Lake Clarkia was a mixed mesophytic forest of hardwoods and conifers. Several taxa appear to have been woody vines (*Siane*) that probably were climbers on other plants of the forest. Some of the smaller plants of the forest were royal and polypody ferns, mosses, horse-tails, and cattails (Smiley and Rember, 1979). Plants dominate the fossils but insects, fish, and diatoms have also been collected. Smiley and Rember (1979) used the numerous taxa to recognize three major habitats: swamp, floodplain-slope, and drier slope.

Clarkia Lake deposits are closely associated with the Columbia River Basalt Group. As previously discussed, the basalt flows have been examined in petrographic, chemical, paleomagnetic, and stratigraphic detail by numerous researchers.

## ROAD LOG TO THE SNAKE, CLEARWATER, AND POTLATCH RIVERS

### INTRODUCTION

The road log to the Snake, Clearwater, and Potlatch rivers is 128 miles long. The trip begins in Moscow and goes to the Snake River via Pullman. Once along the Snake, the trip goes eastward to the Clearwater River and eventually along the Potlatch River (Figure 5). In addition to stops in Columbia River basalt, the trip also contains stops to observe Mesozoic intrusive rocks, Pleistocene flood sediments, plant fossil localities, and large-scale geologic structures.

The Snake, Clearwater, and Potlatch rivers road log is well suited for introducing the geology of the Moscow-Pullman area. It also serves as an introduction to Columbia River basalt stratigraphy. For both these reasons, this trip should be the first taken of the road logs in this field guide. Since many of the stops are at lower elevations along the three rivers, the trip can be driven in the winter months.

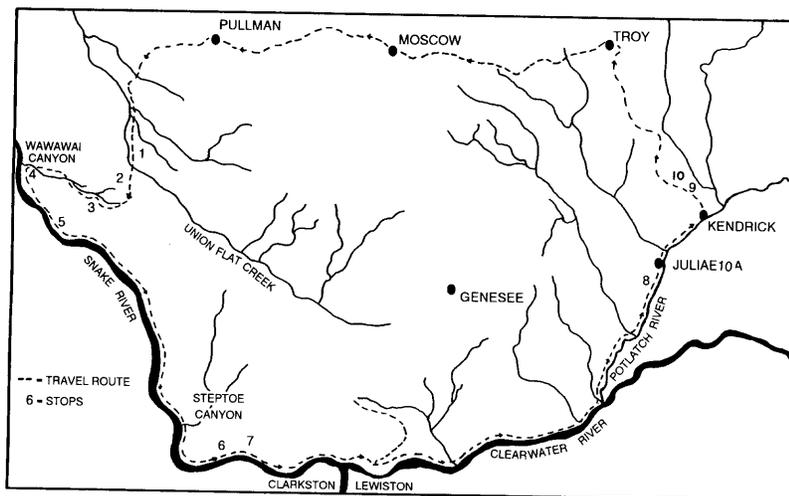


Figure 5. Index map showing the route of travel and the locations of stops for the road log to the Snake, Clearwater, and Potlatch rivers.

### MILEAGE AND DESCRIPTIVE LOG

Mileage is reported as a cumulative amount (Cum.) — the distance traveled from the road log's starting point, and as an interval number (Int.) — the distance between points or stops.

MILEAGE	DESCRIPTION
Cum.	Int.
0.0	Starting point is at the junction of Line Street and ID-8 in Moscow. Proceed west toward Pullman on ID-8. Stop locations are indicated on Figure 5.
1.3	1.3 Idaho-Washington state line. Highway changes to WA-270.
2.5	1.2 Small roadcuts in the Priest Rapids Member of the Wanapum Formation.

- 3.9 1.4 Basalt quarry on the south side of the highway. A Pullman water test well (488 m deep) was drilled about 150 meters west of the county road on the north side of the creek (Brown, 1976). Chemical analyses of well cuttings revealed the Wanapum-Grande Ronde contact at a depth of 30 meters (Brown, 1976). The contact is marked by a predominantly clay interval 4 meters thick.
- 7.1 3.2 Major quarry operation on south side of the highway exposes a Wanapum flow of the Priest Rapids Member.
- 8.2 1.1 Entrance to Washington State University. Continue straight ahead through Pullman and follow signs to Spokane. Stay in right lane.
- 8.9 0.7 Turn right and follow signs toward Spokane. Move to left lane.
- 9.0 0.1 Junction with US-195 and WA-270. Turn left to Colfax on US-195. Outcrops of basalt on the south side of the highway are Priest Rapids Member. Along the north side of the valley, a few meters above the valley floor, are exposures of siltstones with plant debris. This thin interbed (about 3 m thick) separates the Wanapum and Grande Ronde Formations in the Pullman area.
- 9.7 0.7 Move to left lane and turn left from US-195 onto Wawawai Road.
- 11.5 1.8 Junction of Wawawai Road and US-195. Proceed straight ahead on Wawawai Road.
- 15.3 3.8 Highway follows Union Flat Creek on the right.
- 17.0 1.7 **STOP 1:** Outcrops of Priest Rapids Member on left. The Priest Rapids Member of the Wanapum Basalt forms the valley floor of Union Flat Creek. The Priest Rapids is, in turn, overlain by the Saddle Mountains Basalt in the higher elevations. Saddle Mountains and Wanapum flows can be individually mapped using chemical, field, and paleomagnetic criteria. For this trip, the Saddle Mountains and Wanapum Basalts can be distinguished in the field from the underlying Grande Ronde flows by the presence of abundant to sparsely scattered plagioclase or olivine phenocrysts. Look closely at hand samples at this stop so that you can compare them with Grande Ronde Basalt at Stop 3. In volume and thickness, the Saddle Mountains and Wanapum flows form only a thin skin over the underlying Grande Ronde flows in this area.
- 21.1 4.1 **STOP 2:** Turn sharp right just after ridge top onto dirt road. The ridge is the drainage divide between Union Flat Creek, a mature system, and Wawawai Canyon, a youthful system. Drive about 150 meters up the road. On a clear day, numerous high peaks can be seen in the distance. Due north is the cone-shaped Steptoe Butte; N. 20°E. is Kamiak Butte; N.50°E. is the Palouse Range (Moscow Mountain); and due east is Bald Butte. The basalt flow beneath this locality is one of the youngest Saddle Mountains flows on the plateau proper. From this view it is possible to see how the older metamorphic and intrusive rocks rise above the loess-mantled Columbia River basalt.
- Return to highway and turn right. The highway from this point descends rapidly to the Snake River canyon, going down

- stratigraphic section through the Wanapum and a major part of the Grande Ronde.
- 22.0 0.9 Junction with Wawawai Road. Turn right.
- 23.0 1.0 **STOP 3:** Outcrops on left with red-oxidized flow top. Good exposure of Grande Ronde flows, which are consistently fine grained to very fine grained and aphyric. Groups of Grande Ronde flows can be correlated by using a combination of magnetostratigraphy and the recognition of high titanium, low magnesium, and high magnesium flows (Swanson and others, 1980). Grande Ronde flows crop out all the way to the river.
- 24.6 1.6 The white material exposed across the drainage (west) is a reworked deposit of Mazama Ash. Several exposures of this ash are visible in stream drainages along the Snake River.
- 27.5 2.9 **STOP 4:** Entrance to Wawawai County Park. Turn right and proceed ahead to parking area. Basalt flows lie directly ahead on the south side of the river. Similar to the north side, most of the sequence consists of Grande Ronde with a thin skin of Wanapum flows at the very top. Saddle Mountains Basalt was not mapped on the top of the plateau along its southern edge directly ahead (Swanson and others, 1980). Wawawai County Park is built on Pleistocene flood sediments, which were deposited in most of the side drainages of the Snake River between here and Lewiston. Walk about 150 meters northwest across grassy hills to a nearly overgrown south-facing gravel pit exposing 3 meters of flood sediments. At least six "packages" or "cycles" consist of coarse granules at the base, fining upward to fine loess caps. Locally, these are crosscut by small clastic dikes.
- 27.9 0.4 Return to park entrance and turn right.
- 28.7 0.8 Wawawai Landing and Recreational Area on right.
- 29.3 0.6 Gentle westward dip of Grande Ronde flows can be seen along south side of river.
- 30.7 1.4 **STOP 5:** Stop at turnout on the right along outcrops of light-colored rocks. The area is locally referred to as Granite Point. The bulk of the rocks at Granite Point are coarse grained and granitic in composition (Hooper and Rosenberg, 1970). Crystals of quartz and light-colored potassium feldspar of greater than average size can be seen in hand specimen, the feldspar exhibiting distinct marginal zones reminiscent of rapakivi texture (Hooper and Rosenberg, 1970). Biotite is abundant and occurs in vague bands, which are partly responsible for the slight foliation characteristic of the rock. The foliation is enhanced by feldspar elongation and oriented "sheetlike" segregation of biotite, hornblende, small crystals of apatite, and deep red-brown sphene. The granite is overlain by Grande Ronde Basalt (N<sub>2</sub>) and contains a weathered horizon exposed along the north side of the railroad tracks (Figure 6). The intrusive rocks apparently are the most westward member of a series of hills and ridges of prebasalt, granitic Cretaceous-aged rocks that extend into eastern Washington from Idaho, south of Moscow.
- 33.6 2.9 Milepost 19.



Figure 6. Mesozoic granite rocks overlain by Grande Ronde Basalt at Granite Point.

- 36.6 3.0 Blyton Landing on right.
- 37.1 0.5 Basalt pillows and zones of palagonite exposed along railroad tracks over the next 6 miles. Pillows and interbasalt sediments are rare in the Grande Ronde Basalt in the central part of the basin. The flows were extruded in a relatively short time, and in many places there was not enough time for drainages and sediments to be developed. Eastward toward the paleotopographic highs, the Grande Ronde flows thin and pinch out, and sediments become increasingly common between flows. The eastward pinching and thinning were caused by the rapid basining of the plateau over the Pasco-Richland area in south-central Washington, as the basalt flows attempted to fill up the "pot." The Grande Ronde Basalt poured out in more than 120 flows over a period of 1.5 million years (Reidel and others, 1989).
- 40.2 3.1 Radiating columns form two large circular-shaped features in the flow above the railroad tracks. The origin of these features could be pre-flow channels, or they may represent filled lava tubes.
- 43.1 2.9 Nisqually Landing.
- 43.5 0.4 Highway crosses railroad tracks.
- 45.5 2.0 Junction with Steptoe Road. Turn right. The dip of the flows changes on the south side of the river.
- 46.5 1.0 At this point the Vista fault intersects the Snake River and extends into the canyon directly south of the river. This location is at the northwestern end of the Lewiston basin where the east-west Vista fault of Swanson and others (1980) and the Lewiston structure of Camp (1976) change directions and swing southwestward. The Lewiston structure includes an anticlinal wedge pushed up between a vertical fault to the

south and a high angle reverse fault to the north (Camp and Hooper, 1981).

- 48.9 2.4 **STOP 6:** Excellent view of the Lewiston structure (Figure 7). The anticlinal wedge exposes Imnaha Basalt along the highway. These flows can be traced to where they dip southward beneath the hogbacks of Grande Ronde Basalt visible directly ahead. Imnaha Basalt weathers to a distinctive light gray color. On fresh surfaces, it is medium to coarse grained and plagioclase phyric with phenocrysts up to 5 centimeters in length.



Figure 7. View of Lewiston structure, looking east along the Snake River.

- 51.1 2.2 **STOP 7:** Pre-Saddle Mountains paleo-Snake River channel exposed to the southeast across the Snake River. On the east end of the outcrop are flows of the Elephant Mountain and Pomona Members, which fill in an irregular surface cut into Grande Ronde Basalt. Numerous exposures in the Lewiston-Clarkston area have Saddle Mountains Basalt in channels cut into Wanapum or Grande Ronde Basalt. Many researchers, for example Camp (1976), Hooper and Camp (1981), and Camp and Hooper (1981), have referred to similar outcrops from the Lewiston area westward to the Pasco-Richland area of south-central Washington. These outcrops show that the Lewiston structure and basin began to form primarily after Wanapum extrusion, which ended about 14.5 m.y. ago (Martin, 1989). From that time until 6 m.y. ago, basalt flows poured into and out of the Lewiston basin. At times these flows traveled down the Snake River all the way to the area of Pasco, Washington.
- 52.1 1.0 On the south side of the river, flows are visible dipping gently eastward and southward into the Lewiston basin.
- 54.2 2.1 Junction with Red Wolf Crossing Bridge (WA-128 West). Outcrops with red scoria are in Grande Ronde. Continue

- directly ahead on WA-128 East.
- 55.8 1.6 Idaho-Washington state line.
- 57.2 1.4 Junction with Spiral Highway. Continue directly ahead on ID-128 East.
- 58.1 0.9 Turn left onto US-12 East.
- 58.2 0.1 Stop. Turn left and continue on US-12. Follow the highway signs to Missoula.
- 59.3 1.1 Potlatch Corporation paper plant on south side of Clearwater River.
- 61.8 2.5 Outcrops over the next few miles are complex due to faults and local landslides.
- 65.9 4.1 Junction of US-12 and US-95. Bear right on US-12 to Missoula.
- 70.8 4.9 Junction of US-12 and ID-3. Turn left on ID-3 to Juliaetta.
- 75.0 4.2 **STOP 8:** Small turnout on right about 30 meters past milepost 4. The light-colored rocks are claystones and siltstones of a sediment sequence between Imnaha and Grande Ronde flows (Figure 8). This interbed contains occasional leaf imprints of

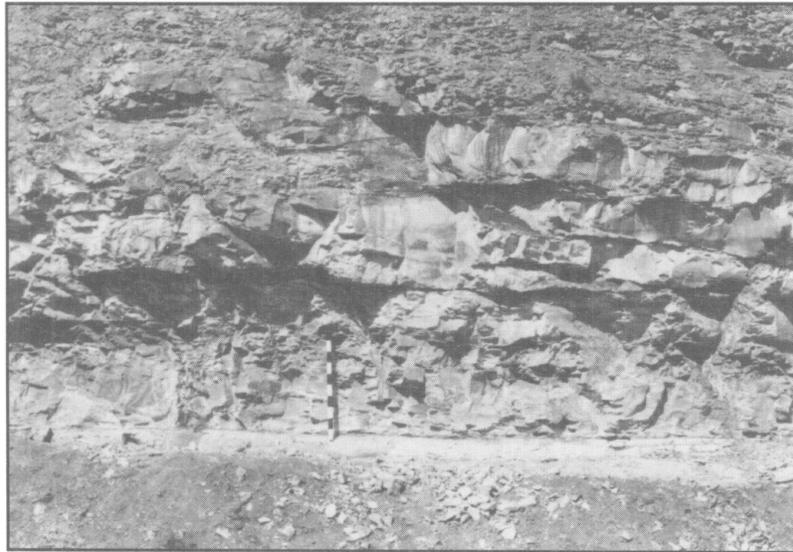


Figure 8. Interbed of claystone and siltstone near Juliaetta, Idaho. One-meter-long staff for scale.

shrubs and trees. Similar interbeds in the region contain entire preserved leaves, fish, and insects. The sediments were deposited in ponds, lakes, and streams. These interbeds increase in frequency and thickness to the east toward the more mountainous country underlain with rocks of the Idaho batholith and Belt Supergroup. Many lakes and ponds were created as a result of the damming of drainage systems by extruding basalts. The types of leaves in the interbeds are similar to dicots, presently growing in the southeastern United States, which indicate that the climate in northern Idaho was milder and more humid 16 m.y. ago.

- 78.4 3.4 Entering Juliaetta. Continue straight ahead.

- 83.1 4.7 Entering Kendrick. Continue straight ahead.
- 85.0 1.9 Junction of ID-3 and County Highway P1. Continue straight ahead. Figure 9 is a stratigraphic section for the sequence exposed for the next 4 miles. On the left, columns with variable orientations appear in the Grande Ronde outcrop (Figure 10). These orientations are probably due to the irregular cooling surfaces formed when the basal Grande Ronde flows filled narrow canyons of the steep prebasalt topography in this area. Basement granitic and metamorphic rocks underlie the communities of Kendrick and Juliaetta.

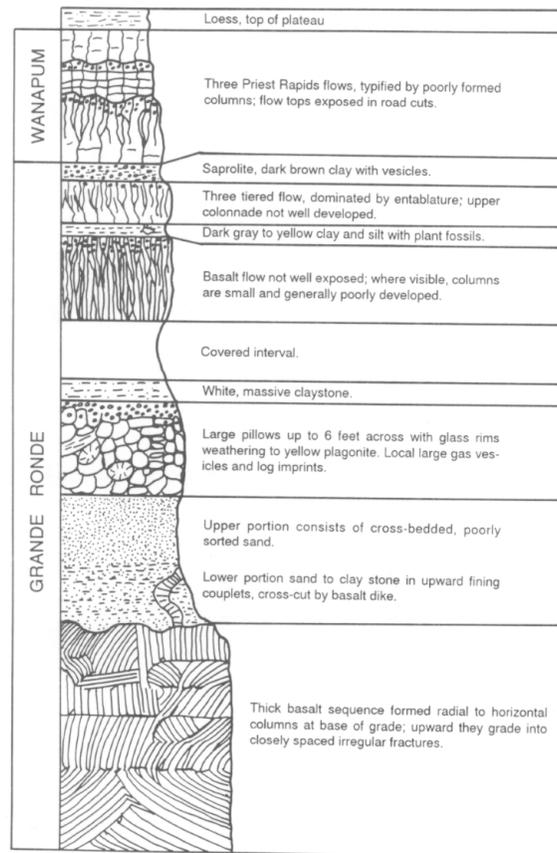


Figure 9. Stratigraphic column of Columbia River basalts, Deary grade on ID-3 (Scale 1"=160").

- 86.0 1.0 Small turnout on right. On the left, the exposure of an interbed is above an irregular flow top of underlying Grande Ronde Basalt (Figure 11). The interbed consists of upward-fining packages of coarse-grained sand to fine claystone.
- 86.4 0.4 Small turnout on right. Excellent exposure of iron-stained interbed of cross-bedded sand (Figure 12). This sequence overlies the finer grained sediments. Together, they represent an upward-coarsening, thick (about 65 m) interbed between two Grande Ronde flows. The sand consists of poorly sorted angular grains of quartz with lesser amounts of muscovite and biotite. The cross-beds are unusually large (over 5 m in height)

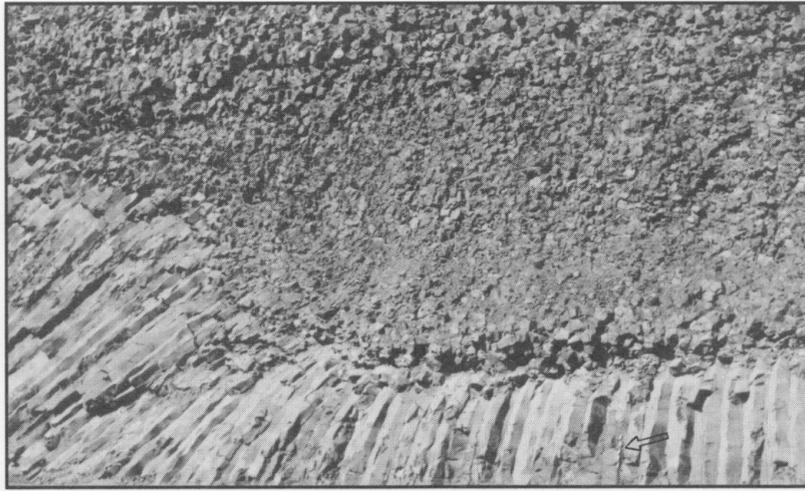


Figure 10. Basalt columns with variable dips on Grande Ronde exposure at the base of the Deary grade on ID-3. Arrow points to one-meter-long staff for scale.



Figure 11. Interbed above Grande Ronde flow consisting of upward-fining packages of coarse-grained sand to fine claystone. One-meter-long staff for scale.

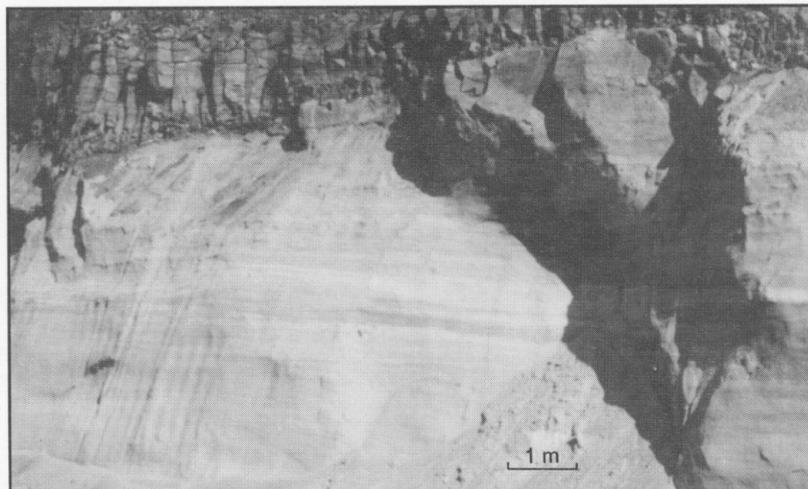


Figure 12. Iron-stained interbed of cross-bedded sand along Deary grade on ID-3. One-meter-long scale.

for a Columbia River basalt interbed. They were probably deposited as a delta in a deep body of water at this locality.

- 86.5 0.1 Exposures of a Grande Ronde flow dominated by large pillow lavas (Figure 13). Several petrified logs were found when the original roadcut was completed. The thick unit of pillows would suggest a deep body of water was present at this locality.

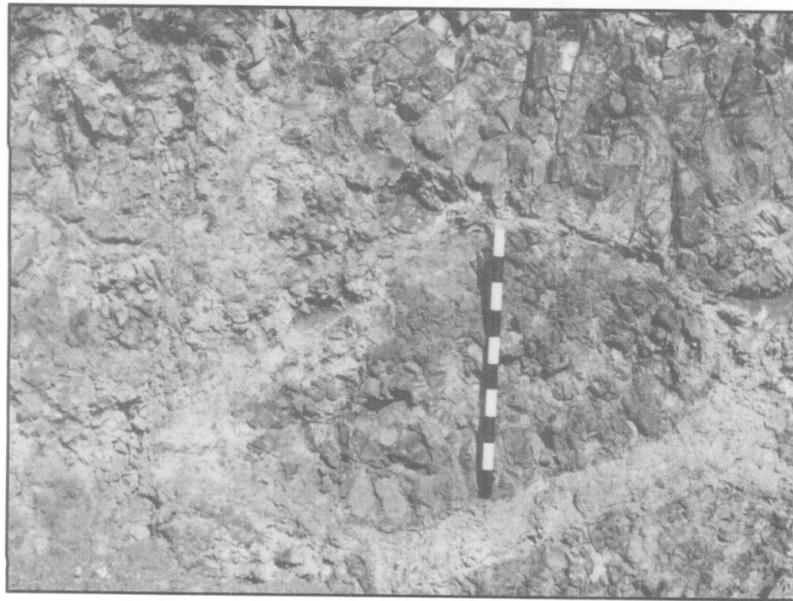


Figure 13. Pillow lavas exposed along Deary grade on ID-3. One-meter-long staff for scale.

- 87.9 1.4 **STOP 9:** Turnout on right side of highway. Beginning from 150 meters down the highway, the sequence consists of a yellow interbed, a Grande Ronde flow, a brown-white saprolite, and a Priest Rapids flow. The saprolite formed by intense weathering after the last Grande Ronde flow. The saprolite can be examined at the north end of the exposure where fresh basalt grades upward into highly weathered basalt that in turn grades upward into "vesicular" clay. Stop 1 of the Lewiston-Clarkston road log provides a discussion of the interpretations made from the saprolite horizons. The lowermost interbed contains plant fossils in a dark gray claystone about 1 meter from the contact with the overlying flow.
- 88.3 0.4 The highway crosses Priest Rapids flows, which cap the Columbia Plateau along its eastern borders.
- 88.8 0.5 **STOP 10:** Small turnout on right side of highway on top of plateau. From this locality one can visualize how the Columbia River basalts lapped against existing highs as they filled the paleo-valleys. The Palouse Range is visible to the northwest, and Potato Hill is to the north. On a clear day other peaks of basement rocks are visible to the east and west. Continue ahead on ID-3 to Deary.
- 99.8 11.0 Junction of ID-3 with ID-8. Turn left on ID-8 to return to Moscow, about 25 miles away.

End of log

## ROAD LOG TO THE COLUMBIA RIVER BASALT VENTS

### INTRODUCTION

Beginning in Moscow, the road log to the Columbia River basalt vents is about 170 miles long and loops into southeastern Washington, through the towns of Palouse and Winona to Lower Granite Dam, and then back to Moscow. The stops emphasize vent areas for the basalt and their stratigraphic relationships.

The vent trip is entirely on paved roads and can be conducted during the spring, summer, and fall seasons. The trip would be most informative after the road log to the Snake, Clearwater, and Potlatch rivers has been completed. Figure 14 illustrates the route.

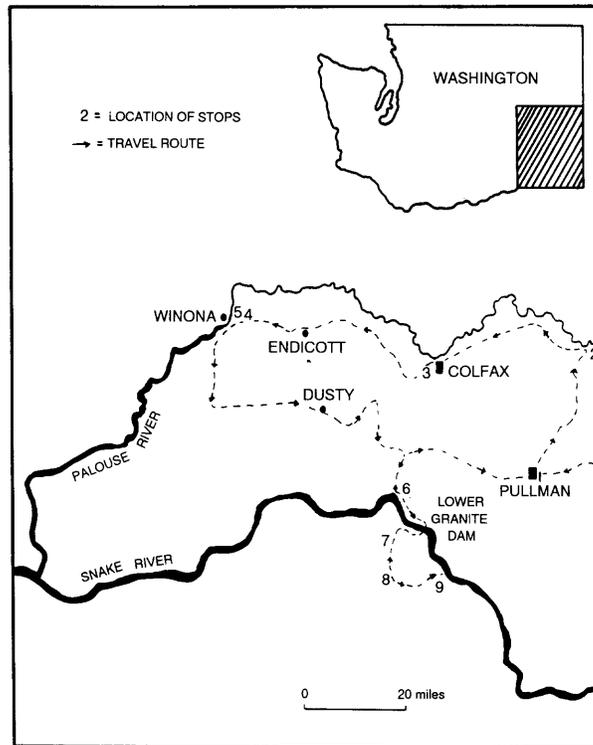


Figure 14. Index map showing the route of travel and the locations of stops for the Columbia River basalt vent trip.

### MILEAGE AND DESCRIPTIVE LOG

Mileage is reported as a cumulative amount (Cum.) — the distance traveled from the road log's starting point, and as an interval number (Int.) — the distance between points or stops.

#### MILEAGE      DESCRIPTION

Cum.    Int.

0.0                  Starting point is at the junction of Line Street and ID-8 in Moscow. Proceed toward Pullman on ID-8.

- 1.3 1.3 Idaho-Washington state line. Highway changes to WA-270.
- 2.5 1.2 Small roadcuts in basalt. These flows are correlative with the Priest Rapids Member of the Wanapum Formation.
- 3.7 1.2 Basalt quarry on the south side of the highway. The Pullman water test well (323 m deep) was drilled about 150 meters west of the county road on the north side of the creek. Chemical analyses of well-chip samples revealed the Wanapum-Grande Ronde contact at a depth of 30 meters (Brown, 1976). The contact is marked by a predominantly clay interval 4 meters thick.
- 6.9 3.2 Major quarry operations on south side of highway expose the Lolo flow of the Priest Rapids Member.
- 7.7 0.8 Junction of WA-270 and Johnson Road. Turn left and continue to bear left. Sign points to Spillman Agriculture Farm. Cross railroad tracks. Stay on Johnson Road. The signs read "Johnson Ave" in places.
- 8.3 0.6 **STOP 1:** Outcrop of Priest Rapids Member (Lolo chemical type) on north side of road. In the eastern one-third of the exposure is a 3- to 4-meter-wide basalt dike. Upon close inspection of the dike, chill margins can be identified on the outer edges of the smaller, horizontal columns. Chemical data have shown that the dike is not similar to the Lolo flow it crosscuts. In addition, its magnetic polarity is normal, whereas the Lolo flow's polarity is reversed.
- 8.4 0.1 Junction with railroad tracks. Turn around and return on Johnson Road to WA-270.
- 9.0 0.6 Junction of Johnson Road and WA-270. Turn left towards Pullman.
- 9.2 0.2 Entrance to Washington State University. Continue directly ahead. Follow WA-270.
- 9.9 0.7 Turn right toward Spokane. Stay in right lane.
- 10.0 0.1 Junction of WA-270 and WA-27. Continue straight ahead on WA-27 toward Palouse. Although few rocks are exposed in downtown Pullman, results from drill hole data and rocks studied just west of town reveal that the junction is on the Wanapum-Grande Ronde contact. In Pullman, the Lolo flow is separated from the underlying Grande Ronde by a thin interbed of sand and clay, and the Roza and Frenchman Springs Members are absent.
- 10.1 0.1 Intersection of WA-27 and Whitman Street. Continue straight ahead.
- 10.7 0.6 Intersection of WA-27 and Stadium Way. Continue straight ahead toward Palouse on WA-27.
- 16.9 6.2 Kamiak Butte is visible to the west (Figure 15). Kamiak Butte consists of poorly bedded coarse-grained quartzite. The quartzite strikes east-west, and the southern slope of the butte is essentially a dip slope of the quartzite modified by minor faulting. Savage (1973) considered this quartzite to be Pre-



Figure 15. View of Kamiak Butte, looking west from WA-27.

cambrian, equivalent to some part of the Ravalli Group of the Belt Supergroup. He believed that Kamiak Butte is basically a fault block that lies in a major northwest- to southeast-trending disturbed belt, which cuts across Benewah, Kootenai, Latah, Whitman, and Spokane counties in Idaho and Washington.

Hooper and Webster (1982) tentatively correlated Kamiak quartzite to similar quartzite of northeast Washington that is Cambrian in age. The rock is distinct from the impure, laminated, finer grained quartzite of the Belt Supergroup further east in Idaho.

- |      |  |
|------|--|
| 21.6 | 4.7 Junction with Kamiak Butte Road.   |
| 24.4 | 2.8 Outskirts of Palouse.  |
| 24.6 | 0.2 Railroad tracks.   |
| 24.9 | 0.3 Bridge over Palouse River. Junction of WA-27 and WA-272. Turn right on WA-272. Continue straight ahead.  |
| 25.3 | 0.4 <b>STOP 2:</b> Just after crossing the railroad tracks, pull over and park in small turnout to the right. The basalt here belongs to the nonporphyritic Wanapum Formation. At least four major lithologic units are exposed in the roadcut opposite the turnout. These are listed in Table 1 from oldest unit 1 to youngest unit 4. In addition to the basalt in the roadcut, rock units are visible in the small quarry across the county road and along the railroad tracks. The exposure is probably very near a vent of nonporphyritic Wanapum Basalt. This interpretation is based primarily on the material (bombs, spatter, pumice) exposed at the south end of the exposure (Figure 16). The palagonite breccia that overlies the interbed contains near-vent material. Thus, the roadcut is probably a cross-section of a small low-lying Wanapum spatter cone. |

Table 1. Major Stratigraphic Units in Small Roadcut, Palouse, Washington.

Unit	Description
4	Fine-grained, gray basalt typical of nonporphyritic Wanapum flows. At the north end of the exposure, these basalts exhibit typical columnar features. Unit 4 unconformably overlies units 1-3.
3	Palagonite breccia, poorly bedded, containing volcanic bombs, pumice, scoria, and angular basalt fragments.
2	Upward-fining sequence of light-colored fine sand, silt, and clay. Scattered pieces of plant debris can be found at top.
1	Highly weathered, partly consolidated pumice, spatter, cinders, and bombs.

25.7	0.4	Turn around and return to junction of WA-272 and WA-27. Turn right on WA-27.
25.9	0.2	Follow highway signs to Spokane. Turn left on WA-272 at sign to Colfax.
26.4	0.5	Outcrops along Palouse River are the Priest Rapids Member. Highway crosses two railroad tracks.
37.1	10.7	Junction on right with road to Glenwood. The road to Glenwood goes down stratigraphic section, from the Priest Rapids and Roza Members of the Wanapum Formation into the underlying Grande Ronde. The Roza, which is missing at Pullman, is about 30 meters thick at this locality. Continue straight ahead.
41.4	4.3	Highway begins to descend into Colfax. The outcrops at the top of the grade are the Priest Rapids Member, which are underlain by the Roza Member.
42.1	0.7	Outcrops of the Roza Member. The Roza Member is 65 meters thick in Colfax and crops out all the way to the base of the grade.
42.3	0.2	Junction of WA-27 and US-195 in Colfax. Turn right on US-195. Move to the left lane.
42.9	0.6	Junction of US-195 and US-26. Turn left on US-26 to Walla Walla and Vantage.
43.0	0.1	<b>STOP 3:</b> Park near stop sign. The outcrops directly ahead are Grande Ronde. They are overlain by 3 meters of sand, silt, and clay, which is in turn overlain by the Roza Member of the Wanapum Formation. Walk up Green Hollow Road to a small quarry where pillows of the Roza Member are in contact with the interbed. Grande Ronde flows consist of fine-grained to very fine-grained aphyric basalt. The Roza flow is characterized by large, evenly distributed, conspicuous plagioclase phenocrysts with minor microphenocrysts of olivine and augite. Continue west on US-26.

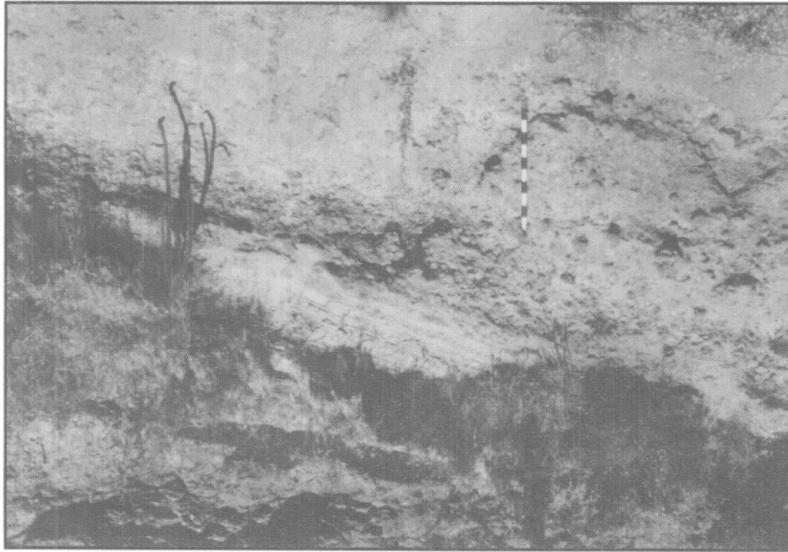


Figure 16. Exposure of volcanic bombs, spatter, and pumice below light-colored interbed of sand, silt, and clay near Palouse, Washington. One-meter-long staff for scale.

- 43.8 0.8 Large quarry ahead is in the Roza Member.
- 46.7 2.9 Junction with secondary paved highway to Winona. Turn right and continue past Whitman County Fairgrounds.
- 51.8 5.1 Town of Diamond.
- 62.0 10.2 Town of Endicott. Outcrops along road are the Priest Rapids Member.
- 66.2 4.2 Reworked Mazama Ash exposed along creek banks.
- 67.7 1.5 **STOP 4:** The roadcut east of Winona corresponds to locality 5 of Swanson and others (1975, Table 1). Bedded Roza pumice and spatter that are relics of cones and ramparts are visible here. Narrow dikes cut the pumice deposit. The Roza flow caps the outcrop, and thin flows are interbedded with the pumice. From this stop, travel ahead and pull off to left just past the intersection into a small gravel parking lot alongside railroad tracks.
- 68.1 0.4 **STOP 5:** Railroad cut across the Palouse River from Winona. Walk carefully across railroad bridge from small parking area. This outcrop corresponds to locality 4 of Swanson and others (1975, Table 1). Here relic spatter cones and ramparts of Roza lithology are scoured and highly modified in shape by the "bulldozer action" of the thick, overlying Roza flow. Portions of the outcrop consist of basaltic pumice. It is easy to imagine how quickly such tephra could be eroded away were it not for a protective capping of some sort (in this case, thick basalt flows). Probably cones and tephra deposits like these were formed at most Wanapum vents, only to be removed before being covered by the next flow. According to Swanson and Wright (1976), these localities are about 12 miles south of the northernmost known Roza vents, whereas the southernmost known Roza vents are 120 miles away near the Oregon border. Swanson and Wright (1976) calculate the eruption rate for the Roza member to be 1 cubic kilometer per day. They base this calculation on observed dimen-

sions of the vent system and the Shaw and Swanson (1970) rheologic model.

From the parking lot, turn right and proceed south towards LaCrosse.

- 68.8 0.7 Small outcrop of Priest Rapids Member (Lolo chemical type) overlies the Roza everywhere in this area.
- 71.4 2.6 Three-way road junction. Bear right. The highway follows the easternmost tract of the Channeled Scablands. Isolated islands of loess are visible ahead.
- 72.1 0.7 Sharp left turn across railroad tracks. The road from here to LaCrosse is near the Priest Rapids-Roza contact.
- 79.1 7.0 Entrance to LaCrosse. Turn left, cross railroad tracks, and turn right. Continue through town. Follow highway signs to Dusty.
- 81.3 2.2 Junction with US-26. Turn left.
- 93.5 12.2 Junction to Walla Walla. Continue east on US-26.
- 101.7 8.2 Junction with secondary paved road (Summers Road) just beyond milepost 125. Turn right (south) to Boyer Park.
- 102.0 0.3 Outcrops along road are the Roza Member.
- 103.5 1.5 Outcrops in quarry are the Roza Member. Platy jointing is similar to Roza outcrops at other localities in southeastern Washington.
- 105.9 2.4 Small unnamed intersection. Bear right toward Boyer Park on Almota Road.
- 110.9 5.0 Unnamed intersection. Turn right, just beyond the white church, to Almota and Boyer Park.
- 113.3 2.4 Small roadcut in Priest Rapids flow.
- 113.8 0.5 Roadcut shows Roza Member resting on tuffaceous sedimentary rocks that overlie saprolite developed on the Grande Ronde Formation. No Frenchman Springs flows are present.
- 114.0 0.2 Sequence of the Grande Ronde flows. Outcrops all the way to the base of the grade are in the Grande Ronde Formation.
- 117.2 3.2 Railroad underpass at base of grade. Turn Left.  
**STOP 6:** It is necessary to park across from the underpass and proceed on foot. Exposed along the road are outcrops of a flow top. This flow top can be traced for several miles along the Snake River. As you drive past it later, note how it rises in elevation.
- 118.6 1.4 Entrance to Boyer Park.
- 120.7 2.1 Sharp right turn toward Lower Granite Dam. Several types of columnar basalt are exposed to the north just before the turn. The flow is composed of a basal colonnade, which grades upward into an upper flow top, without an entablature. However, the overlying flow exhibits a basal colonnade, with overhanging entablature, which is typical of many Grande Ronde flows (Figure 17).
- 121.0 0.3 Entrance to Lower Granite Dam. Traffic is generally allowed to cross during daylight hours.

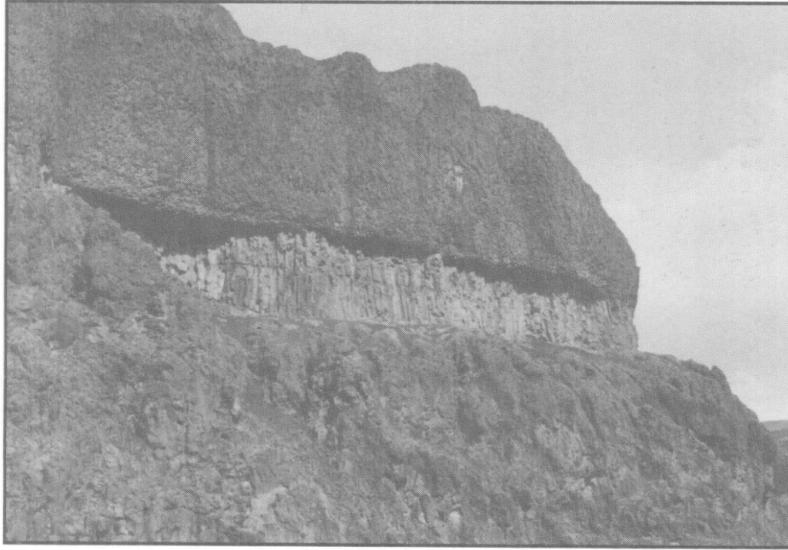


Figure 17. Grande Ronde flow, at the north entrance of Lower Granite Dam, exhibiting entablature and colonnade. The entablature is 8 meters thick.

- |       |     |   |
|-------|-----|---|
| 121.8 | 0.8 | Small "Y" intersection at base of dam. Continue straight ahead.   |
| 124.2 | 2.4 | Road begins up a grade of large gravel deposit.   |
| 125.5 | 1.3 | Excellent view of Grande Ronde Basalt along both sides of the river.  |
| 126.1 | 0.6 | Outcrop on ridge to the left is a remnant of the Lower Monumental flow, an intercanion basalt flow of the Saddle Mountains Formation.   |
| 127.0 | 0.9 | Road takes a sharp left and begins to climb up a grade.   |
| 128.0 | 1.0 | Three dikes with plagioclase phenocrysts are exposed within a distance of 300 meters. According to Swanson and Wright (1976), two are Roza chemistry, and the third has a composition unlike most of the other flows.   |
| 128.3 | 0.3 | Thin Grande Ronde flows. Some with very oxidized flow tops.   |
| 129.2 | 0.9 | Roza dike exposed along highway (Figure 18).  |
| 129.4 | 0.2 | <b>STOP 7:</b> Small turnouts on left. Park in the first available one. Walk back to examine Roza dike, which corresponds to locality 9 of Swanson and others (1975, Table 1). Swanson and Wright (1976) believe the thin Grande Ronde flows at this locality may imply nearby vents. |
| 129.9 | 0.5 | The Grande Ronde-Wanapum contact is defined by a brown saprolite zone and is overlain by Frenchman Springs flows, which are 20 to 25 meters thick at this locality.   |
| 130.1 | 0.2 | Two Frenchman Springs flows contain scattered phenocrysts of plagioclase.   |
| 130.3 | 0.2 | Outcrops of the Roza Member are separated from Frenchman Springs outcrops by a thin, discontinuous siltstone.   |
| 130.9 | 0.6 | Roadcut consists of two thin flows of the Roza Member, which according to Swanson and Wright (1976) are separated by welded spatter material. The site corresponds to locality 5 of Swanson and others (1975, Table 1).   |



Figure 18. Roza dike along highway, 5.5 miles south of Lower Granite Dam. One-meter-long staff for scale.

- 131.4 0.5 Downtown Mayview.
- 133.7 2.3 Sharp right curve. Junction with two roads. Turn left on second road, named Tramway Road.
- 135.0 1.3 **STOP 8:** Gravel storage area. The storage area is on the Priest Rapids Member. Walk over to the canyon edge to view stratigraphic relationships. The Roza Member is present in the cliffs below, but the Frenchman Springs Member is absent. On a clear day Granite Point and the extensive Grande Ronde flows can be seen to the northeast along the Snake River. In addition, Steptoe and Kamiak Buttes may be visible in the distance, protruding above the basalt plateau.

Shortest way to Moscow (50 miles) is to return across Lower Granite Dam.

End of log.

## ROAD LOG TO THE STRATIGRAPHY AND STRUCTURE OF THE LEWISTON-CLARKSTON AREA

### INTRODUCTION

The road log to the Lewiston-Clarkston area explores the structural, volcanic, and stratigraphic relationships of the Columbia River basalt in the Lewiston-Clarkston valley. The 70-mile round trip takes about a half day. Due to the area's low elevations, the trip can generally be taken during any season of the year.

### MILEAGE AND DESCRIPTIVE LOG

Mileage is reported as a cumulative amount (Cum.) — the distance traveled from the road log's starting point, and as an interval number (Int.) — the distance between points or stops.

MILEAGE	DESCRIPTION
Cum.    Int.	
0.0	Mileage begins at the intersection of ID-95 and Palouse River Drive, south of Moscow, near the Chinese Village Restaurant.
1.8    1.8	On the west side of the highway is a sand pit with a house built into bedrock. Exposures consist of biotite gneiss crosscut by small pegmatitic quartz and feldspar dikes. The pit was developed to obtain sand from the weathered portions of the gneiss.
4.6    2.8	Highway steepens as it begins to climb over the southeastern corner of Paradise Ridge. Bald Butte is visible to the right. Paradise Ridge is mapped as Idaho batholith with isolated Precambrian outcrops (Rember and Bennett, 1979). Bald Butte has been mapped by Hooper and Webster (1982) as Cretaceous granitic gneiss, dated by potassium-argon at 69.8 m.y., along with isolated Cambrian(?) outcrops of quartzite. The low areas between Moscow and these higher basement rocks are underlain by Wanapum Basalt of the Columbia River Basalt Group. Wanapum also underlies the low areas south of this ridge to the northern edge of the Lewiston Hill where outcrops of younger Saddle Mountains flows overlie Wanapum.
13.6    9.0	Junction to Genesee.
22.7    9.1	Junction to frontage road. Exposures ahead (0.6 mile) on north side of highway consist of a Saddle Mountains flow (Wilbur Creek Member) overlying a red interbed which in turn overlies the Priest Rapids Member of the Wanapum Formation.
24.0    1.3	<b>STOP 1:</b> Pull over to scenic turnout overlooking Lewiston and Clarkston below and the junction of the Clearwater and the Snake rivers. Hells Canyon of the Snake River is south, and the Clearwater Canyon is east. The small buttes in the distance, capping the plateau to the southwest, are remnant cones of the Roza Member. The flows to the north (across the highway) are nearly horizontal. To the west, the axis of the

Lewiston structure is visible between horizontal flows to the north and hogbacks which dip steeply southward. At this locality, the exposed structure is the north limb of the east-west trending Gaging Station anticline of Camp (1976). Camp (1976) interprets this entire structure, in the elementary sense, as an anticlinal horst that becomes more monoclinial eastward.

Roadcut 0.5 mile down the grade on the north side of the highway consists of, from base upward, red scoria in a Grande Ronde flow, two man-made bench excavations in a Grande Ronde flow, a dark brown saprolite (weathered soil horizon) interval, and an overlying Wanapum flow. Throughout much of the eastern part of the plateau, the saprolite separates Wanapum and Grande Ronde Basalt, suggesting a long period between the eruption of two major basalt groups. Westward, the Grande Ronde flows become more numerous, and the overlying weathered zone is represented in places by either an interbed or a very thin oxidized zone. This stratigraphic relationship was created by basining to the west before and during the eruptions of the Grande Ronde Basalt. Many flows of the Grande Ronde Basalt did not cover isolated highs on the eastern end of the plateau. Therefore, a part of the Grande Ronde Basalt was exposed for a longer time. Continue down the grade.

- 24.6 0.6 Small reverse fault exposed in a red flow top of the Grande Ronde Basalt.
- 24.9 0.3 **STOP 2:** Pull off at scenic turnout. Exposure of Grande Ronde flow on north side of highway displays the development of a colonnade at its base grading upward into the entablature which, in turn, is overlain by an irregular yellow-brown scoria zone representing the top of the flow. On a clear day, the Lewiston basin can be viewed from this overlook. From east to west, the basalt dips into a basin that forms the Lewiston-Clarkston area. The basin contains numerous flows of younger Saddle Mountains Basalt that do not extend northward across the Lewiston structure but that can be traced westward for long distances along the Snake River to as far as the Pasco-Richland area in south-central Washington. This relationship indicates the Lewiston basin developed primarily after the eruption of the Wanapum Basalt (about 14.5 m.y. ago). Therefore, many of the Saddle Mountains flows came into the Lewiston basin and were forced to travel westward down a developed ancestral Snake River drainage.
- 25.3 0.4 Excellent exposure of a Grande Ronde flow contact.
- 25.6 0.3 Highway swings southwestward across the Lewiston structure. At the south end of the third exposure, a fault associated with the folding is visible.
- 26.4 0.8 Southward-dipping Grande Ronde flows evident in exposures. These flows dip below Wanapum and Saddle Mountains flows, which compose the Lewiston basin.
- 28.3 1.9 Junction of US-95 and US-12. Follow US-12 West highway signs to Clarkston-Lewiston-Walla Walla.

- 29.2 0.9 Stop light at the intersection of US-12 and 3rd Avenue N. Continue straight ahead. Follow US-12 West highway signs to Clarkston-Walla Walla.
- 30.1 0.9 Stop light at the intersection of 18th St. and Main. Turn right on US-12.
- 31.7 1.6 Turn left and continue to follow US-12 West signs. Highway will circle around to the Lewiston-Clarkston bridge across the Snake River.
- 32.0 0.3 Lewiston-Clarkston bridge. Move to left lane. The Snake River marks the boundary between Idaho and Washington.
- 32.3 0.3 Junction with WA-129. Bear left on WA-129 South toward Asotin. Continue to follow highway signs towards Asotin. Stay in left lane.
- 32.7 0.4 Stop light at the intersection of Sixth, Diagonal, and Maple streets. Turn left and continue ahead through downtown Clarkston. Follow WA-129 signs.
- 34.3 1.6 Swallows Park on left side of highway.
- 35.6 1.3 Turn right on 13th Street. Basalt ahead at intersection belongs to the Priest Rapids Member of the Wanapum Formation. Large cliffs ahead (known as Swallows Rock) have been mapped as Pomona Member, which here is part of a canyon-filling flow (Hooper and others, 1985).
- 36.5 0.9 Turn left on Peaslee Street.
- 36.6 0.1 **STOP3:** Outcrops on right side across from an auto body shop. Park where possible according to traffic flow. The exposures here display the canyon-filling features of Saddle Mountains flows as well as the bedded near-vent breccia of tephra and obsidian. At least four Saddle Mountains flows are exposed here along with three ash beds and a bedded obsidian-tephra near-vent breccia. The bedded breccia, with overlying basalt, rests in a channel cut into the lower flows (Figure 19).  
Turn around and return to US-12 in Clarkston. Follow highway signs to Walla Walla through Clarkston.
- 41.0 4.4 Junction of WA-129 and US-12. Turn left towards Walla Walla.
- 42.1 1.1 Junction with WA-128. Continue straight ahead. Golf course on left.
- 43.0 0.9 Ahead are the eastward-dipping Grande Ronde flows overlain by Pomona and Elephant Mountain Members of the Saddle Mountains Formation. On the north side of the Snake River, southward-dipping hogbacks of Grande Ronde Basalt, which represent the southern limb of the Lewiston structure, are visible on a clear day. Flows at or near river level along the road on the south side outcrop near the top of the escarpment north of the river. Further along to the west, the hogbacks on the north side end as the flows become more horizontal. This change marks the location of a part of the Lewiston structure (Gaging Station anticline) as it bends southward towards the Snake River, exposing the lower three magnetostratigraphic units of the Grande Ronde as well as the upper part of the underlying Imnaha Basalt.



Figure 19. Saddle Mountains flow resting in a channel cut into another flow along Peaslee Street in Clarkston, Washington. One-meter-long staff for scale.

- 44.8 1.8 **STOP 4:** On the left side of the highway, long near-perfect vertical columns of a thick flow belong to the Pomona Member that has been dated at about 12 m.y. A thin white ash bed is present beneath the exposure. Westward, this flow climbs upward across Grande Ronde flows. The contact represents an erosional unconformity formed by the Pomona Basalt flowing westward in an ancestral Snake River channel cut in Grande Ronde Basalt.
- 48.2 3.4 Exposures on the left of well-formed colonnades with varied, dipping entablature belong to the Pomona Member.
- 49.0 0.8 Bluff on left consists of Lower Monumental Member which represents one of the youngest Saddle Mountains flows (about 6 m.y.). Visible to the right, the thick sequence of Grande Ronde flows can be seen along the Snake River.
- 49.7 0.7 Alpowa Creek. Turn around where possible. There are two ways for returning to Moscow. One is to return via Lewiston on ID-12 and US-95. The other is to cross the Snake River via the Red Wolf Crossing Bridge (WA-128) to the north side of the river and return to Moscow via the Spiral Highway and US-95.

End of log

## ROAD LOG TO THE CLARKIA FOSSIL AREA

### INTRODUCTION

Miocene plant fossils are the destination of the road log to the Clarkia area, about 45 miles east of Moscow. To help with identifying plant fossils, the reader may wish to have a copy of either the *Guidebook and Road Log to the St. Maries River (Clarkia) Fossil Area of Northern Idaho* by Smiley and Rember (1979) or the *Guidebook to the Geology of Northern and Western Idaho and Surrounding Area* edited by Chamberlain, Breckenridge, and Bonnicksen (1989). Both books are available through the publications sales office of the Idaho Geological Survey on the University of Idaho campus. Because these Miocene fossil beds are closely associated with Columbia River basalt flows, it will be helpful for the reader to have completed the Columbia River basalt road log along the Snake, Clearwater, and Potlatch rivers before taking this trip or the Oviatt Creek trip.

The Clarkia road log is about 120 miles long. Depending on access to the fossil site and the length of the individual visit there, the reader should plan for this trip to take most of the day. The trip should not be taken between November 1 and May 1 due to possible heavy snow cover. Figure 20 shows the locations of stops.

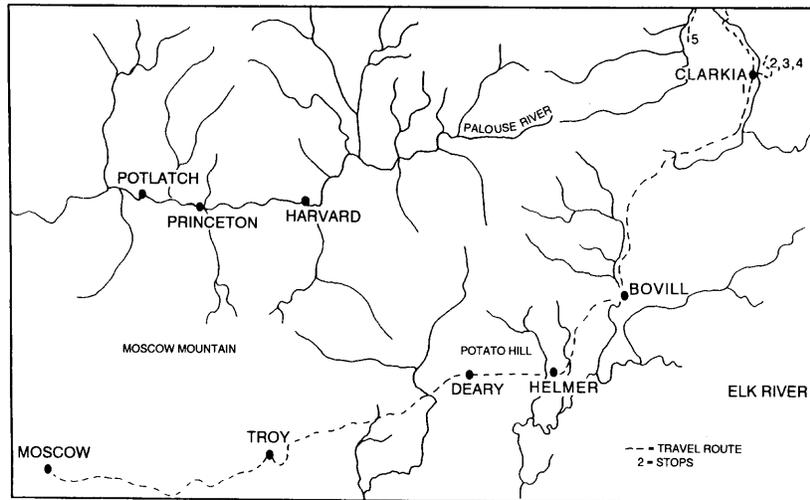


Figure 20. Index map showing the route of travel and the locations of stops for the road log to the Clarkia fossil area.

### MILEAGE AND DESCRIPTIVE LOG

Mileage is reported as a cumulative amount (Cum.) — the distance traveled from the road log's starting point, and as an interval number (Int.) — the distance between points or stops.

#### MILEAGE DESCRIPTION

Cum. Int.

0.0	Starting point is the junction of US-95 and ID-8, South Main Street and Third Street in Moscow. Take ID-8 to Troy. Only a few isolated exposures of basalt are visible over the first 10 miles. This basalt belongs to the Priest Rapids Member of the
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Wanapum Formation that filled valleys between the surrounding hills of the Idaho batholith and Precambrian rocks. The hills and valleys are mantled by Pleistocene loess referred to as the Palouse Formation.

- 11.4 11.4 Troy city limits. Proceed straight ahead. The clay for A.P. Green Refractories Company was mined from nearby clay deposits. Most of the clay is pre-Pleistocene in age.
- 12.1 0.7 Junction of ID-99 and ID-8. Bear left on ID-8 to Deary.
- 13.1 1.0 Basalt outcrops overlying baked sediments on right belong to Wanapum Formation. Petrified wood fragments have been collected from this locality (Figure 21).



Figure 21. Wanapum flow over interbed, 1 mile east of Troy, along ID-8. Exposure is about 9 meters high.

- 16.0 2.9 Roadcut exposes the contact between two flows near road level from which a silicified tree log has been collected and identified as sweet gum. At the top of the outcrop of Priest Rapids Basalt is a channel occupied by white clay (Figure 22). The clay deposits are thought to be alluvial and derived from weathered soils developed on the Idaho batholith and related outcrops.
- 20.0 4.0 Directly ahead is a view of Potato Hill, primarily a light pink to gray rhyolite and dark purple to black volcanic breccia. The rocks have not been accurately dated. The breccia contains xenoliths of Belt-like metamorphic rocks and Idaho batholith-like igneous rocks. No xenoliths of basalt have been noted, and field relations suggest that they are overlain by Miocene Columbia River basalt. Rember and Bennett (1979) list the age of the Potato Hill volcanic rocks as Eocene to Oligocene.
- 23.1 3.1 Junction of ID-9 and ID-8. Continue straight ahead on ID-8.
- 23.3 0.2 Deary city limits. Continue straight ahead.
- 24.9 1.6 Outcrops along railroad tracks on left are Potato Hill volcanic rocks.

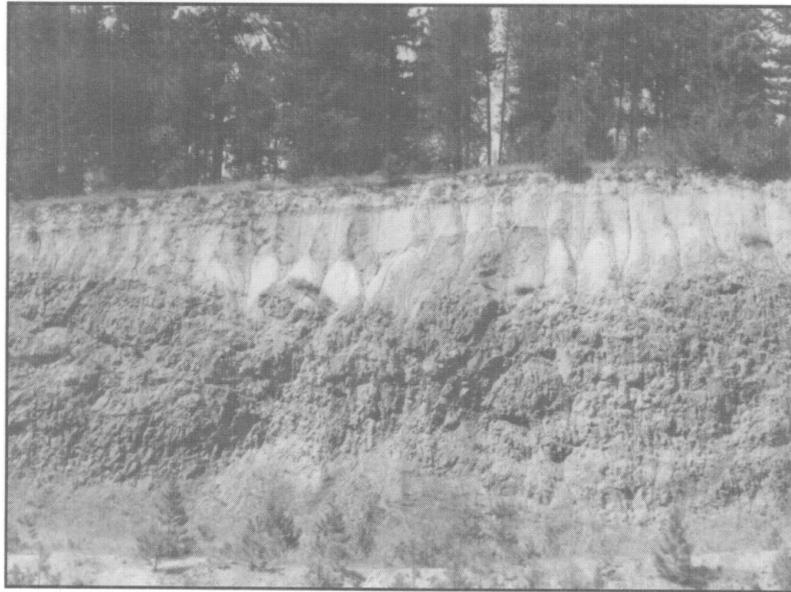


Figure 22. Channel in a Priest Rapids flow occupied by white clay along ID-8 between Deary and Troy. The clay is about 5 meters thick at the apex of the channel.

- 27.8 2.9 Town of Helmer is on Columbia River basalt. White clay deposits are exposed in roadcuts just east of town.
- 29.1 1.3 Railroad crossing.
- 29.7 0.6 Hog Meadow, on left, is probably underlain by Miocene lacustrine sediments (Smiley and Rember, 1979).
- 32.4 2.7 White clay pits barely visible to the left. The Simplot Company originally developed these pits, which extend for a couple of miles north to just west of Bovill. The clay deposits are high in aluminum and have been used for refractory bricks.
- 33.8 1.4 Junction of ID-8 and ID-3. Turn left on ID-3 into Bovill and proceed through town.
- 35.0 1.2 Small outcrops on left are Precambrian mica schists.
- 37.8 2.8 Railroad crossing.
- 40.3 2.5 Roadcuts to the top of the pass consist of weathered Cretaceous granitic rocks intruded into underlying Precambrian units. The pass is part of a ridge that served to delimit the southern extent of Miocene Clarkia Lake.
- 43.0 2.7 Latah-Shoshone County line.
- 44.8 1.8 Milepost 50.
- 45.1 0.3 Roadcuts in Precambrian gneiss on the north flank of the granite-cored ridge.
- 46.2 1.1 Flat valley floor is underlain by Clarkia deposits near the south end of Miocene Clarkia Lake.
- 46.8 0.6 **STOP 1:** Type locality for the Clarkia fossil beds is to the left of the highway on the north curve of the Fossil Bowl Race Track owned by Francis Kienbaum. This location contains the best fossils in the Clarkia area. For further information,

see Smiley and Rember (1981; 1985a; 1985b), Gray (1985), Lewis (1985), and Smiley (1989). Permission for collecting must be obtained from the owner of the land, Mr. Kienbaum. The south end of the track is cut into a hill of weathered Precambrian schist. The road log by Smiley and Rember (1979) contains excellent photographs of the plant fossils from this locality.

- 48.4 1.6 On left, roadcut exposes the nose of a spur of Precambrian rocks along the edge of Clarkia Valley.
- 48.7 0.3 Townsite of Clarkia. Turn right and proceed through town.
- 49.1 0.4 Turn left beyond general store on unnamed street.
- 49.6 0.5 Rock quarry. Precambrian rocks are cross-cut by a diorite dike. Turn left just beyond bridge.
- 49.8 0.2 **STOP 2:** Junction of unnamed roads. Walk about 0.4 mile north to a small rock quarry. Enroute are roadcuts through Precambrian basement rocks. The exposures at the quarry are interpreted as a Miocene volcanic vent and contain basalt flows, volcanic ash, scoria cinders and bombs, and charred wood.
- 50.1 0.3 **STOP 3:** Rock quarry and small roadcut. Pillow basalts overlie coarse volcanic ash containing a *Clarkia florule*. White pebbles and boulders in the area represent later deposits that can be located in places throughout the region. Common fossils are false beech, chestnut, hazelnut, alder, oak, and bay.
- 50.8 0.7 **STOP 4:** Roadcut of sand, silt, and laminated clays, with lenses of sand indicating scour and fill activity during the time of deposition. The thin basalt sheet seems to be a sill associated with the thicker dike at right, where the sediments are blackened. Common fossils are false beech, bald cypress, poplar, willow, alder, magnolia, bay, sycamore, cherry, and oak. Return to ID-3.
- 52.8 2.0 Junction with ID-3. Turn right (north) on ID-3 and proceed down the valley of the St. Maries River, enroute to Emerald Creek fossil beds in a western embayment of the Miocene Clarkia Lake.
- 53.2 0.4 National Forest Work Center.
- 54.8 1.6 On left, roadcut through pillow basalts of a Priest Rapids flow.
- 56.1 1.3 Bridge over St. Maries River.
- 57.7 1.6 On right, a roadcut in Precambrian rocks. This is another example of a knoll of basement rock that was above the level of the Miocene valley sediments and basalts.
- 58.4 0.7 Garnet sand shipping point. Turn left (west) here to Emerald Creek fossil beds and garnet collecting area. Rocks of the Priest Rapids flow and the underlying fossiliferous baked sediment are exposed at the road junction.
- 58.5 0.1 Bridge over St. Maries River at juncture with Emerald Creek. Directly ahead the Priest Rapids flow overlies interbeds.
- 61.4 2.9 Garnet mine loading area. Garnets occur in modern stream deposits. They become concentrated in "pockets" after weathering out from nearby exposures of garnet schists. The mining

is done by dredging methods.

- 61.6 0.2 Road junction at confluence of East and West Emerald Creeks. The garnet sand separating mill is on the left. Take right fork across the bridge and continue to bear left at road junctions over next 0.2 mile.
- 61.9 0.3 One of the fossil sites is off the road to the right. Sunshine Mining Company restored the valley bottom after commercial dredging for garnet sands. The surrounding hilly terrain is on Precambrian basement rocks, and the flat valley floor is underlain by Miocene lacustrine deposits. This area has been termed the Emerald Creek embayment of Clarkia Lake (Smiley and Rember, 1979).
- 62.8 0.9 **STOP 5:** Roadcut in claystones on National Forest land. Common fossils are dawn redwood, bald cypress, pine, poplar, alder, birch, chestnut, oak, false beech, monreed, tulip tree, magnolia, bay, sweet gum, sycamore, maple, honey or water locust, black locust, and tupelo.

Return to ID-3. To return to Moscow, two routes are available. One is to turn right on ID-3 and travel to the junction with ID-8 at Bovill and then on ID-8 via Deary and Troy. The other is to turn left on ID-3 and proceed several miles to the junction with ID-6 and left to US-95 via Emida, Harvard, Princeton, and Potlatch. The trip on ID-6 to US-95 covers part of the picturesque White Pine Scenic Route. Both return trips to Moscow are about 60 miles long.

End of log

## ROAD LOG TO OVIATT CREEK

## INTRODUCTION

The road log to Oviatt Creek is only 14 miles long. It begins at Bovill, 34 miles from Moscow on ID-8. The road log to the Clarkia fossil area provides geologic details from Moscow to Bovill. Several geologic features noted on the trip include outcrops of Potato Hill volcanics, rocks of the Belt Supergroup, pegmatitic rocks of the Idaho batholith, and at the end a Miocene fossil site. Part of the trip is over gravel road that in many places is covered with snow from November until late April.

## MILEAGE AND DESCRIPTIVE LOG

Mileage is reported as a cumulative amount (Cum.) — the distance traveled from the road log's starting point, and as an interval number (Int.) — the distance between points or stops.

MILEAGE		DESCRIPTION
Cum.	Int.	
0.0		Starting point begins in Bovill at junction of ID-8 and ID-3. Turn right on ID-8 towards Elk City.
1.1	1.1	Potato Hill volcanic rocks are exposed in roadcut along left side of highway.
2.8	1.7	Priest Rapids Basalt on left side of road.
3.6	0.8	Priest Rapids Basalt overlain by white clay.
4.0	0.4	Outcrops on left side of road are weathered metamorphosed Belt rocks. They consist of biotite gneiss with interlayered schists and are crosscut by light-colored small pegmatitic dikes. These rocks are exposed in roadcuts over the next several miles.
4.7	0.7	Milepost 41.
6.4	1.7	Shoshone-Clearwater County boundary.
11.5	5.1	Turn right toward Little Boulder Campground on FS-1963.
13.6	2.1	Y-junction. Continue straight ahead on FS-1963.
14.5	0.9	Oviatt Creek fossil site on right side of road. Spheroidally weathered basalt marks the base of a flow that overlies an interbed at this locality. Part of the exposure has slumped and covered much of the site with soil and rubble. A little digging may be necessary to examine the interbed and fossils.

The sediments at this locality are primarily very thin-bedded (1 to 2 mm) clay-rich silts, gray to light-brown at the top and underlain by nonstained, coarse sands in the lower part. The bottom of the interbed has not been exposed. The basalt has been radiometrically dated at 12.8 m.y. (Smiley and Rember, 1985b). Fossils are abundant and taxonomically varied. For additional information on the interbeds and their fossils, see Smiley and Rember (1979), Smiley and Rember (1981), Smiley and Rember (1985a), Smiley and Rember (1985b), and Smiley (1989).

Return to Bovill. To return to Moscow, two routes are available. One is to take ID-8 from Bovill and travel via Deary and Troy. The other is to take ID-3 from Bovill several miles via Clarkia to the junction with ID-6 and then left to US-95 via Emida, Harvard, Princeton, and Potlatch. The trip on ID-6 to US-95 covers part of the picturesque White Pine Scenic Route.

End of log

## REFERENCES

- Baksi, A.K., 1989, Reevaluation of the timing and duration of extrusion of the Imnaha, Picture Gorge, and Grand Ronde Basalts, Columbia River Basalt Group, in S.P. Reidel and P.R. Hooper, eds., *Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239*, p. 105-112.
- Brown, J.C., 1976, Well construction and stratigraphic information: Pullman test observation well, Pullman, Washington: Pullman, Washington State University, College of Engineering Research Department, 76/15-6, 35 p.
- Camp, V.E., 1976, Petrochemical stratigraphy and structure of the Columbia River basalt, Lewiston basin area, Idaho-Washington: Pullman, Washington State University Ph.D. dissertation, 201 p.
- , 1981, Geologic studies of the Columbia Plateau: Part 2, Upper Miocene basalt distribution, reflecting source locations, tectonism, and drainage history of the Clearwater embayment, Idaho: *Geological Society of America Bulletin*, v. 92, pt. 1, p. 669-678.
- Camp, V.E., and P.R. Hooper, 1981, Geologic studies of the Columbia Plateau; Part 1, Late Cenozoic evolution of the southeast part of the Columbia River basalt province: *Geological Society of America Bulletin*, v. 92, pt. 1, p. 659-668.
- Chamberlain, V.E., R.M. Breckenridge, and Bill Bonnicksen, eds., 1989, Guidebook to the geology of northern and western Idaho and surrounding area: *Idaho Geological Survey Bulletin 28*, 156 p.
- Choiniere, S.R., and D.A. Swanson, 1979, Magnetostratigraphy and correlation of Miocene basalts of the northern Oregon coast and Columbia Plateau, southeast Washington: *American Journal of Science*, v. 279, no. 7, p. 755-777.
- Gray, Jane, 1985, Interpretation of co-occurring megafossils and pollen: A comparative study with *Clarkia* as an example, in C.J. Smiley, ed., *Late Cenozoic history of the Pacific Northwest: San Francisco, Calif., Pacific Division, American Association for the Advancement of Science*, p. 185-245.
- Hooper, P.R., 1982, The Columbia River basalts: *Science*, v. 215, p. 1463-1468.
- Hooper, P.R., and V.E. Camp, 1981, Deformation of the southeast part of the Columbia Plateau: *Geology*, v. 9, p. 323-328.
- Hooper, P.R., and P.E. Rosenburg, 1970, The petrology of Granite Point, southeastern Washington: *Northwest Science*, v. 44, no. 2, p. 131-142.
- Hooper, P.R., and G.D. Webster, 1982, Geology of the Pullman, Moscow West, Colton, and Uniontown 7.5-minute quadrangles, Washington and Idaho: Washington Department of Natural Resources, Division of Geology and Earth Resources Map GM-26, scale 1:62,500.
- Hooper, P.R., G.D. Webster, and V.E. Camp, 1985, Geologic map of the Clarkston 15-minute quadrangle, Washington and Idaho: State of Washington Department of Natural Resources, Division of Geology and Earth Resources Geologic Map GM-31, scale 1:48,000.
- Jones, J.G., 1968, Pillow lava and pahoehoe: *Journal of Geology*, v. 76, p. 485-488.
- Knowlton, F.H., 1926, Flora of the Latah Formation of Spokane, Washington and Coeur d'Alene, Idaho: U.S. Geological Survey Professional Paper 140, p. 17-81.
- Lewis, S.E., 1985, Miocene insects from the *Clarkia* deposits in northern Idaho, in C.J. Smiley, ed., *Late Cenozoic history of the Pacific Northwest: San Francisco, Calif., Pacific Division, American Association for the Advancement of Science*, p. 245-265.
- Long, P.E., 1978, Characterization and recognition of intraflow structures, Grande Ronde Basalt: Rockwell Hanford Operations Informal Report RHO-BWI-LD-10, 74 p.
- Martin, B.S., 1989, The Roza Member, Columbia River Basalt Group; Chemical stratigraphy and flow distribution, in S.P. Reidel and P.R. Hooper, eds., *Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239*, p. 85-104.
- McKee, E.H., D.A. Swanson, and T.L. Wright, 1977, Duration and volume of Columbia River basalt volcanism, Washington, Oregon, and Idaho: *Geological Society of America Abstracts with Programs*, v. 9, p. 463.
- McMillan, Kent, P.E. Long, and R.W. Cross, 1989, Vesiculation in Columbia River basalts, in S.P. Reidel and P.R. Hooper, eds., *Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239*, p. 157-168.
- Moore, J.G., 1975, Mechanism of formation of pillow lava: *American Scientist*, v. 63, p. 269-277.
- Reidel, S.P., and K.R. Fecht, 1987, The Huntzinger flow; evidence of surface mixing of the Columbia River basalt and its petrogenetic implications: *Geological Society of America Bulletin*, v. 98, p. 664-677.
- Reidel, S.P., T.L. Tolani, P.R. Hooper, M.H. Beeson, K.R. Fecht, R.D. Bentley, and J.L. Anderson, 1989, The Grande Ronde Basalt, Columbia River Basalt Group: Stratigraphic descriptions and correlations in Washington, Oregon, and Idaho, in S.P. Reidel and P.R. Hooper, eds., *Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239*, p. 21-54.
- Rember, W.C., and E.H. Bennett, 1979, Geologic map of the Pullman quadrangle, Idaho: Idaho Bureau of Mines

- and Geology, scale 1:250,000.
- Rietman, J.D., 1966, Remanent magnetization of the late Yakima Basalt, Washington state: Stanford, Calif., Stanford University Ph.D. dissertation, 87 p.
- Savage, C.N., 1973, A geological field trip in Benewah and Whitman counties, Idaho and Washington, respectively, *in* Belt Symposium, v. 1: Idaho Bureau of Mines and Geology, p. 253-307.
- Shaw, H.R., and D.A. Swanson, 1970, Eruption and flow rates of flood basalts, *in* E.H. Gilmour and Dale Stradling, eds., Proceedings of the 2nd Columbia River Basalt Symposium: Cheney, Eastern Washington State College Press, p. 271-300.
- Smiley, C.J., 1989, The Miocene Clarkia fossil area of northern Idaho, *in* V.E. Chamberlain, Roy M. Breckenridge, and Bill Bonnicksen, eds., Guidebook to the geology of northern and western Idaho and surrounding area: Idaho Geological Survey Bulletin 28, p. 35-48.
- Smiley, C.J., and W.C. Rember, 1979, Guidebook and road log to the St. Maries River (Clarkia) fossil area of northern Idaho: Idaho Bureau of Mines and Geology Information Circular 33, 27 p.
- , 1981, Paleoecology of the Miocene Clarkia Lake (northern Idaho) and its environs, *in* Jane Gray, A.J. Boucot, and W.B.N. Berry, eds., Communities of the past: Stroudsburg, Pa., Hutchinson and Ross Publishing Co., p. 551-590.
- , 1985a, Physical setting of the Miocene Clarkia fossil beds, northern Idaho, *in* C.J. Smiley, ed., Late Cenozoic history of the Pacific Northwest: Interdisciplinary studies of the Clarkia fossil beds of northern Idaho: San Francisco, Calif., Pacific Division, American Association for the Advancement of Science, p. 95-112.
- , 1985b, Composition of the Miocene Clarkia flora, *in* C.J. Smiley, ed., Late Cenozoic history of the Pacific Northwest: Interdisciplinary studies of Clarkia fossil beds of northern Idaho: San Francisco, Calif., Pacific Division, American Association for the Advancement of Science, p. 11-31.
- Swanson, D.A., J.L. Anderson, R.D. Bentley, V.E. Camp, J.N. Gardener, and T.L. Wright, 1979, Reconnaissance geologic map of the Columbia River Basalt Group in Washington and adjacent Idaho: U.S. Geological Survey Open File Report 79-1363, scale 1:250,000.
- Swanson, D.A., and T.L. Wright, 1976, Field guide to field trip between Pasco and Pullman, Washington, emphasizing stratigraphy, vent areas, and intra-canyon flows of the Yakima Basalt, *in* Proceedings, Geological Society of America Cordilleran Section meeting, Pullman, Washington: Pullman, Washington State University Department of Geology, Field Guide 1, 33 p.
- Swanson, D.A., T.L. Wright, V.E. Camp, J.N. Gardener, R.T. Helz, S.M. Price, S.P. Reidel, and M.E. Ross, 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Investigations Map I-1139, scale 1:250,000.
- Swanson, D.A., T.L. Wright, and R.T. Helz, 1975, Linear vent systems and estimated rates of magma production and eruption for the Yakima Basalt on the Columbia Plateau: American Journal of Science, v. 275, p. 877-905.
- Swanson, D.A., T.L. Wright, P.R. Hooper, and R.D. Bentley, 1979, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p.
- Tolan, T.L., S.P. Reidel, M.H. Beeson, J.L. Anderson, K.R. Fecht, and D.A. Swanson, 1989, Revisions to the estimates of the areal extent and volume of the Columbia River Basalt Group, *in* S.P. Reidel and P.R. Hooper, eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 1-20.
- Tomkeiff, S.I., 1940, Basalt lavas of the Giants Causeway: Bulletin of Volcanology, v. 2, p. 89-145.
- Wright, T.L., M.J. Grolier, and D.A. Swanson, 1973, Chemical variation related to the stratigraphy of the Columbia River basalt: Geological Society of America Bulletin, v. 84, p. 371-386.