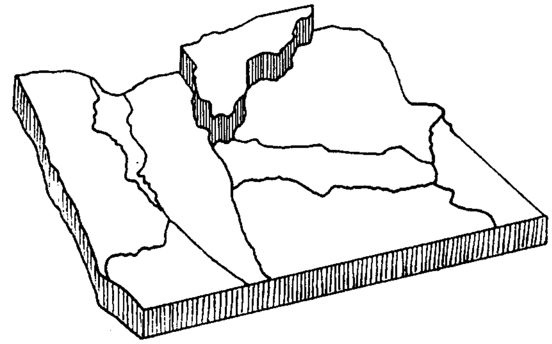
Deschutes-Columbia Plateau

Physiography

The Deschutes-Columbia River Plateau is predominantly a volcanic province covering approximately 63,000 square miles in Oregon, Washington, and Idaho. The plateau is surrounded on all sides by mountains, the Okanogan Highlands to the north in Washington, the Cascade Range to the west and the Blue Mountains to the south in Oregon, and the Clearwater Mountains in Idaho to the east. Almost 200 miles long and 100 miles wide, the Columbia Plateau merges with the Deschutes basin lying between the High Cascades and Ochoco Mountains. The province slopes gently northward toward the Columbia River with elevations up to 3,000 feet along the south and west margins down to a few hundred feet along the river.

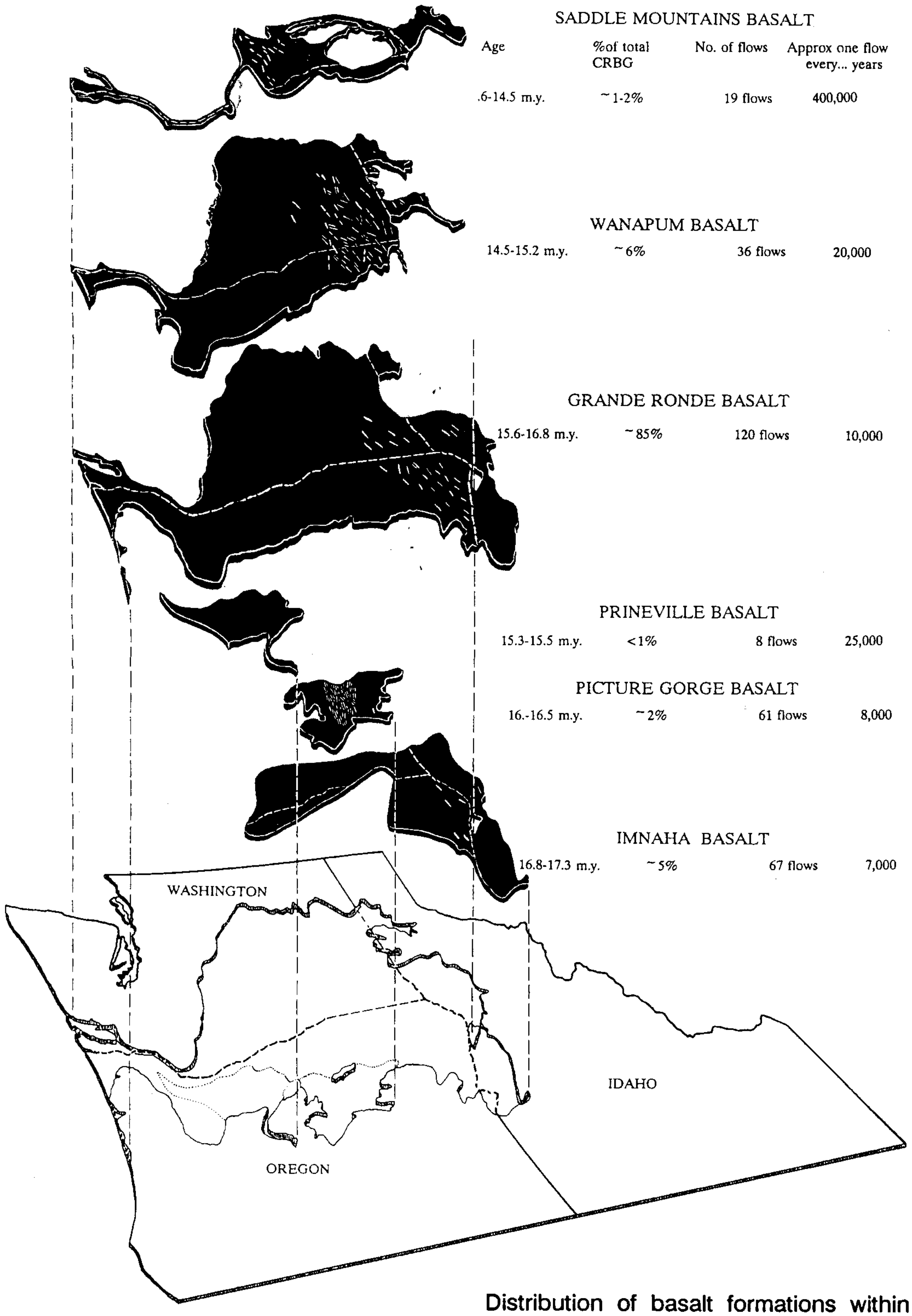
Primary rivers in the province are the west-flowing Columbia River and its tributaries, the northward flowing Deschutes, John Day, and Umatilla rivers, along with Willow and Butter creeks, all of which enter the Columbia between The Dalles and Wallula Gap. The third largest river in North America, the Columbia has the greatest impact on the plateau. Beginning in British Columbia on the slopes of the Canadian Rockies, the Columbia runs from the north to Wallula Gateway where it makes a sharp bend toward the west. Its watershed covers 259,000 square miles primarily in southwest Canada, southern Washington, and northern Oregon. Although smaller than the the Columbia, the Deschutes River crosses the province in a northerly direction to be joined by the Crooked and Metolius rivers south of Lake Simtustus. From its beginning as small streams near Mt. Bachelor, the Deschutes extends 250 miles before entering the Columbia just west of Biggs. These streams have cut intricate, deep canyons into the virtually horizontal lavas of the plateau. Divides between the canyons are dissected, but broad, flat uplands remain.



Geologic Overview

Geologic events in the Columbia-Deschutes province took place on a grand scale. Immense outpourings of lavas during the Miocene created one of the largest flood basalt provinces in the world, second only to the Deccan Plateau in India. Erupting from source vents in central and northeast Oregon as well as in southeast Washington and adjacent Idaho, flow after flow of basalts filled a subsiding basin to create a featureless plateau. This volcanic activity was followed by falling ash and lavas expelled from ancestral Cascade volcanoes aligned on the western border of the Deschutes Basin. Disrupted and blocked by the lavas, sediment-laden streams and the Deschutes River carried the material northward, depositing much of it along the channel filling the broad alluvial plain of the basin. With the gradual subsidence of the Cascade vents into a deep graben or depression and the resulting high Green Ridge escarpment, the accumulation of volcanic debris in the Deschutes basin shifted to lavas from small local cones during the Pliocene. In the Pliocene waters trapped behind structural ridges formed temporary lakes and ponds that filled with sediment. A broad uplift of the plateau triggered an aggressive new erosional phase where rivers carried away much of the unconsolidated clay, silt, and sand and cut deep channels. Volcanism here ceased after massive lavas from near Newberry Volcano entered the deep canyons, once again disrupting the flow of the rivers.

Vast lake waters, impounded by glacial ice, impacted the Columbia Plateau during the Pleistocene when they were released from Montana sending catastrophic floods across the landscape to scour southeastern Washington and the Columbia gorge.

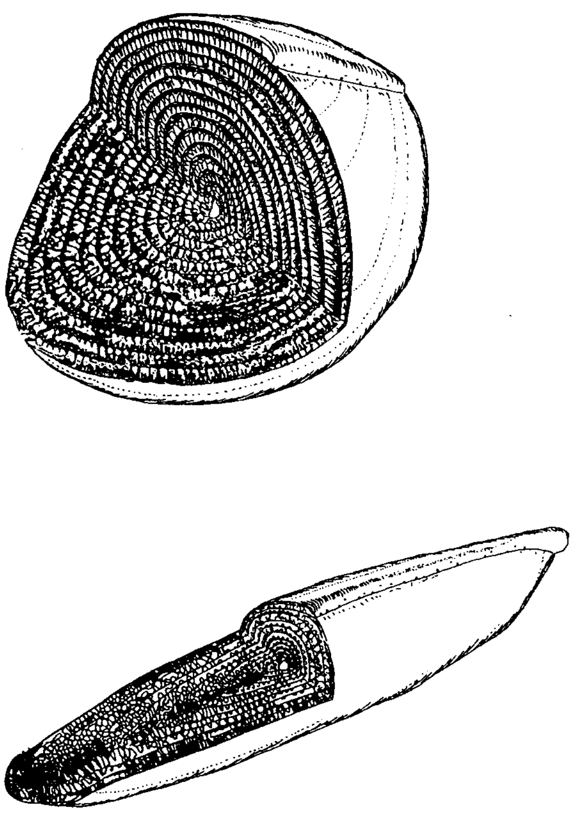


Distribution of basalt formations within the Columbia River Group (after Beeson and Moran, 1979; Beeson, Tolan, and Anderson, 1989)

Geology

Small exposures of Paleozoic and Mesozoic rocks as well as parts of the Eocene, Oligocene, and Miocene Clarno and John Day formations that extend into the Columbia-Deschutes province from the south are treated with the Blue Mountains province.

The oldest rock known from the Columbia-Deschutes province is a single stone discovered near the base of Gray Butte in Jefferson County. Fusulinids, or fossil protozoa, extracted from the loose boulder were dated as late Permian, approximately 250 million years old. More remarkably, these fossils are of a variety typical only to the eastern Pacific regions of Japan, Timor, and China. Although the affinity of this rock was puzzling when it was discovered in the middle 1930 s, with the present knowledge, it can be related to one of the many exposures of displaced terranes found today in the eastern Blue Mountains. The stone was evidently eroded from one of the terranes before being transported by streams to the western part of the Columbia-Deschutes province.



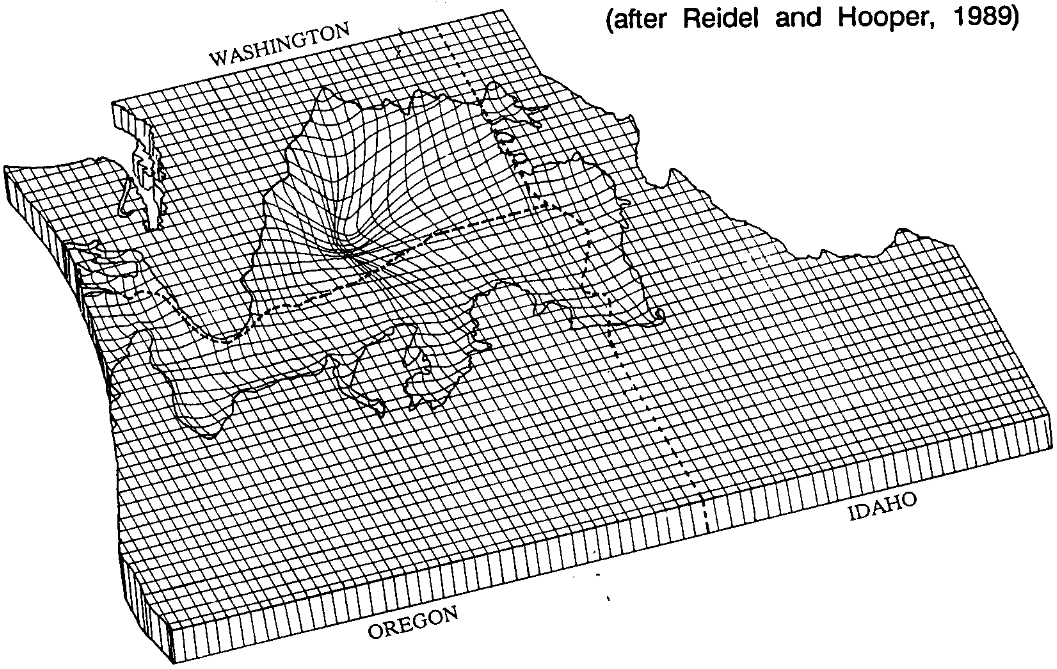
Comparison of Permian fossil fusulinids from the Orient (upper) and North America (lower) (specimens are 1/2 inch in length)

Miocene

Geologic study of the Columbia Plateau focuses upon the basalts that flooded this province, an episode that took place during the middle to late Miocene, 17 to 6 million years ago. Eruptions occurred on the average of one flow every 35,000 years with an output per flow of over 100 cubic miles of basalt. Larger eruptions, however, encompass over 500 cubic miles of basalt for a single flow. Thick, successive outpourings of lava spread over the landscape often moving at a speed of up to 30 miles an hour to form the Columbia River basalts, the primary group in the plateau today. Covering an area only slightly less than the entire state of Washington, the total volume of basalt, which was over 42,000 cubic miles, would be enough to construct a wall of lava one mile wide and almost 2 miles high around the earth. The thickness of individual flows is variable, but several flows up to 200 feet are known. Spreading across the Deschutes-Columbia River Plateau, the spoon-shaped mass of basalt is over 3 miles thick beneath Yakima and Pasco, Washington, thinning to the south from a mile thickness along the Columbia River to a feather edge within the Blue Mountains province. This suggests that the lava was extruded into a basin that subsided progressively with succeeding flows.

Some of the most extensive of the Columbia River flows may have taken decades to cool and harden. Cooling proceeds in a lava flow from the top down and from the bottom upward. Typical lava flows in cross-section have two distinct layers that have been named after parts of Greek temples. The lower portion or colonnade is so-called because the basalt has cooled and contracted to form columns perpendicular to the cooling surface below. The remaining section of the flow, which constitutes up to 4/5 of the entire mass, is the entablature with multiple directions to the columns. Near the top of the entablature, the basalt may be vesicular from gas which has come out of solution in the molten lava to form bubbles. Often these gas bubbles leave long vertical tubes or pipes through the lava to mark where the gas escaped.

There is disagreement with respect to exactly how lava in flood basalts flowed. As the lava moved, a thin surface skin may have hardened only to break up so that the new flow would look like a wall of broken rock rising up to 10 stories high. Inside the flow the lava was fluid, but at the base, along the top, and at the snout, it is armored by sharp, blocky pieces of broken, cooled basalt. The veneer of broken chunks atop the lava tends to roll over as the flow spreads, developing a steep, irregular front. As the lava moves farther from its source, the edge becomes progressively thinner until it is only a few stories high. At some point the lava,

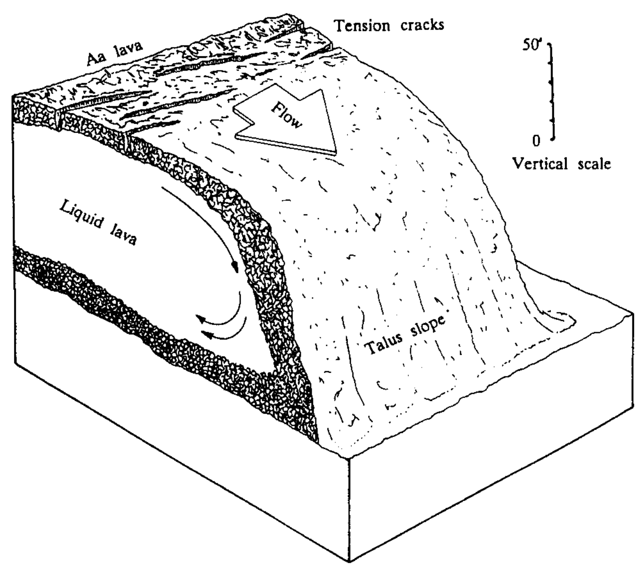


The Columbia River Basalt Group develops its maximum thickness of nearly 15,000 feet under the Columbia Plateau near Yakima, Washington (after Reidel and Hooper, 1989)

unable to push through the mound of hardened, rough rock along the edges, comes to a stop, essentially dammed up by its own cooled crust.

The relationship between the Columbia-Deschutes Plateau and the surrounding provinces is unclear because thick lavas obscure the deep crust which has not been well-studied. Crustal thickness in this province has been estimated between 15 to 20 miles. In the 1980s, a series of four wildcat wells were drilled through the lavas in the vicinity of Yakima, Washington, by Shell Oil Company. Targeted were Cretaceous and Tertiary rocks lying below the basalt along older anticlinal structures that were judged to have sufficient organic content and porosity to produce gas. Although the potential reservoir rocks were dry, rocks of the predicted formations were encountered by drilling deep beneath the basalt.

Of the four main formations making up the Columbia River lavas, the oldest is the Imnaha Basalt, followed by the Grande Ronde Basalt, the Wanapum Basalt, and finally the youngest Saddle Mountains Basalt, with the Grande Ronde composing more than 85% of the formations by volume. The Grande Ronde, Wanapum, and Saddle Mountains were formerly lumped together and designated the Yakima Basalts, but they are now distinguished by subtle differences in mineralogy and texture. Variations in magnesium oxide, titanium oxide, and phosphorus are also used to characterize individual flows.

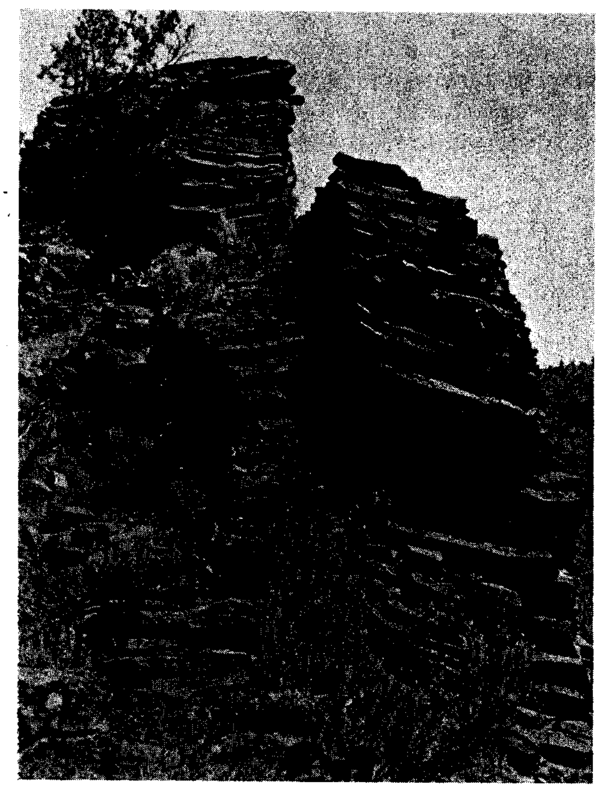


One model for the movement of lava in an Aa flow

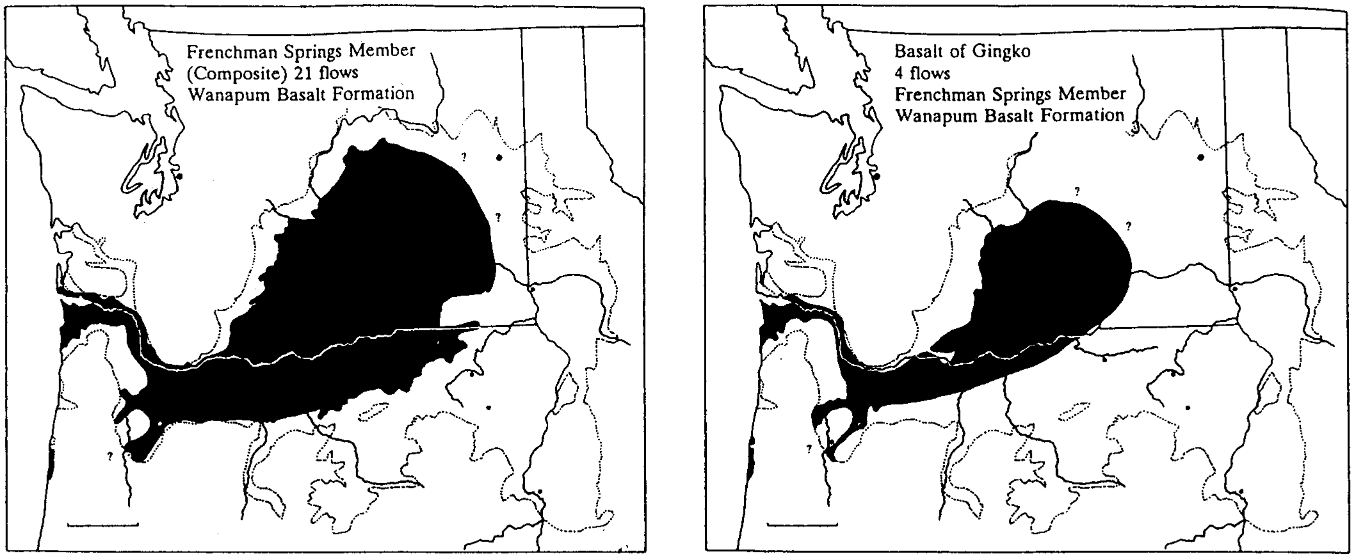
SERIES		GROUP	FORMATION	MEMBER	ISOTOPIC AGE (m.y.)
MIOCENE	UPPER	COLUMBIA RIVER BASALT GROUP	SADDLE MOUNTAINS BASALT	LOWER MONUMENTAL MEMBER	6
				Erosional Unconformity	
				ICE HARBOR MEMBER	8.5
				Basalt of Goose Island	
				Basalt of Martindale	
				Basalt of Basin City	
				Erosional Unconformity	
				BUFORD MEMBER	
	MIDDLE			ELEPHANT MOUNTAIN MEMBER	10.5
				Erosional Unconformity	
				POMONA MEMBER	12
				Erosional Unconformity	
				ESQUATZEL MEMBER	
				Erosional Unconformity	
				WEISSENFELS RIDGE MEMBER	
				Basalt of Slippery Creek	
				Basalt of Tenmile Creek	
				Basalt of Lewiston Orchards	
				Basalt of Cloverland	
				ASOTIN MEMBER	13
				Basalt of Huntzinger	
				Local Erosional Unconformity	
				WILBUR CREEK MEMBER	
				Basalt of Lapwai	
				Basalt of Wahluke	
				Local Erosional Unconformity	
				UMATILLA MEMBER	
				Basalt of Sillusi	
				Basalt of Umatilla	
				Local Erosional Unconformity	
			WANAPUM BASALT	PRIEST RAPIDS MEMBER	14.5
				Basalt of Lolo	
				Basalt of Rosalia	
				Local Erosional Unconformity	
				ROZA MEMBER	
				FRENCHMAN SPRINGS MEMBER	
				Basalt of Lyons Ferry	
				Basalt of Sentinel Gap	
				Basalt of Sand Hollow	15.3
				Basalt of Silver Falls	
				Basalt of Ginkgo	
				Basalt of Palouse Falls	
				ECKLER MOUNTAIN MEMBER	
				Basalt of Shumaker Creek	
				Basalt of Dodge	
				Basalt of Robinette Mountain	
				Local Erosional Unconformity	
			GRANDE RONDE BASALT	SENTINEL BLUFFS UNIT	15.6
				SLACK CANYON UNIT	
				FIELD SPRINGS UNIT	
				WINTER WATER UNIT	
	LOWER		PRINEVILLE BASALT	UMTANUM UNIT	
				ORTLEY UNIT	
				ARMSTRONG CANYON UNIT	
				MEYER RIDGE UNIT	
				GROUSE CREEK UNIT	
				WAPSHILLA RIDGE UNIT	
				MT. HORRIBLE UNIT	
			PICTURE GORGE BASALT	CHINA CREEK UNIT	
				DOWNEY GULCH UNIT	
				CENTER CREEK UNIT	
				ROGERSBURG UNIT	
				TEEPEE BUTTE UNIT	
				BUCKHORN SPRINGS UNIT	16.5
			IMNAHA BASALT	See Hooper and others (1984) for Imnaha Units	17.5

Basalt stratigraphy within the Columbia River Basalt Group (Beeson and Moran, 1979; Beeson, Tolan, and Anderson, 1989).

The oldest of the formations, the Imnaha Basalt, originated from vents and fissures along the Snake and Imnaha rivers in northeast Oregon, southeast Washington, and Idaho spreading along the Imnaha River in northeast Oregon. Following this 16.5 million years ago, large volumes of Grande Ronde basalts erupted with a frequency of one flow for every 10,000 years slowing to one flow for each 20,000 and 400,000 years for the Wanapum and Saddle Mountains lavas respectively. In a process that extended less than 1 million years, Grande Ronde basalts poured from fissures and cracks as much as 100 miles long in a complex network of openings in the crust known as the Chief Joseph dike swarm that extended from southeastern Washington and northeastern Oregon along a well-defined trend. Reaching westward all the way to the Pacific Ocean, many of the 120 individual Grande Ronde lavas spread out for as much as 460 miles and are among the most extensive on earth. Lava from these separate flows was so runny that it did not mound up to form volcanoes but rapidly filled in surface depressions to produce a flat topography. Following the Grande Ronde eruptions, 36 separate flows of the Wanapum lavas poured out over a 1 million year interval nearly covering the plateau, while the Saddle Mountains Basalt, with 19 flows, was mainly confined to the central part of the Columbia basin. To



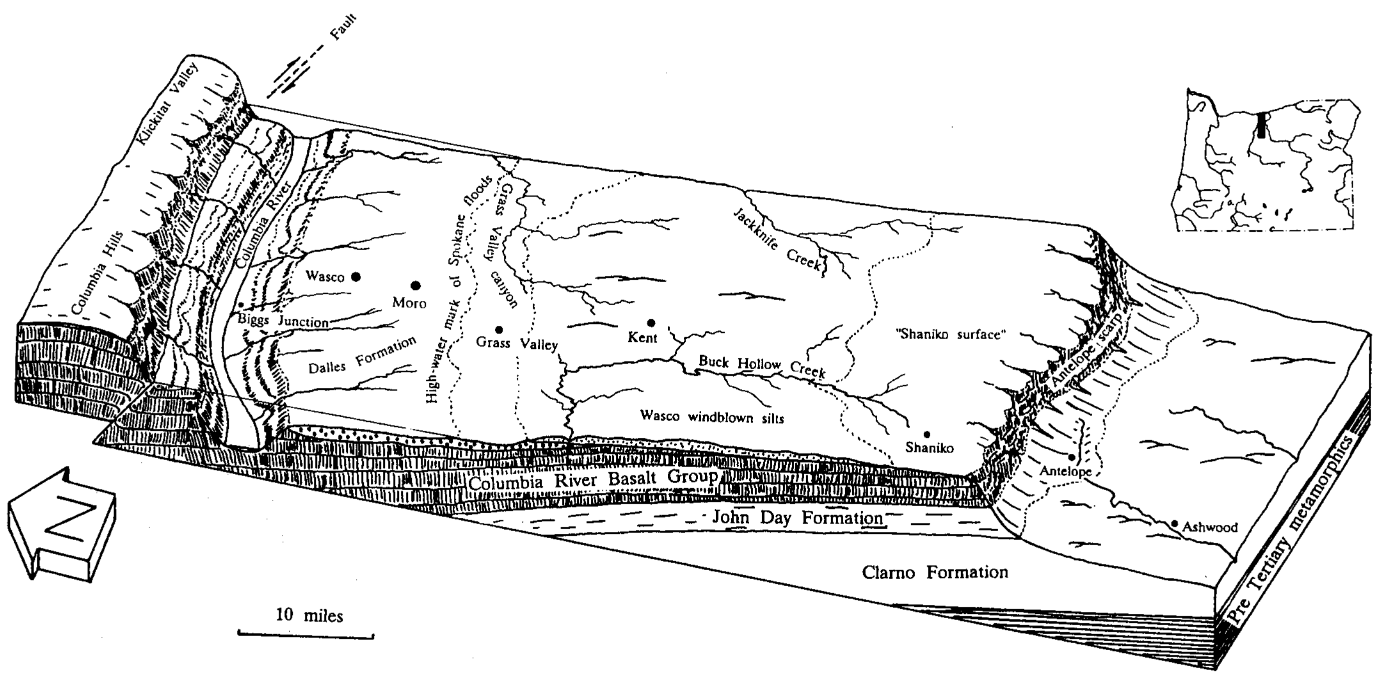
Dikes of the Grande Ronde basalt (photo courtesy Oregon Department of Geology and Mineral Industries).



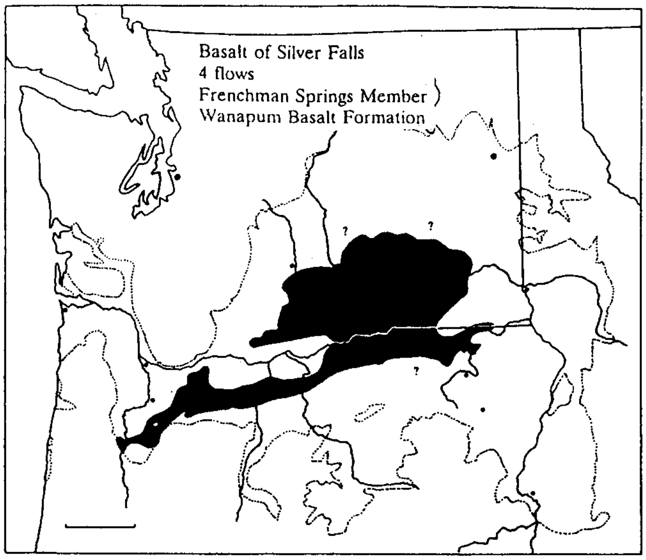
Geographic distribution of individual flows and members of the Columbia River Basalt Group (after Reidel and Tolan, 1989)

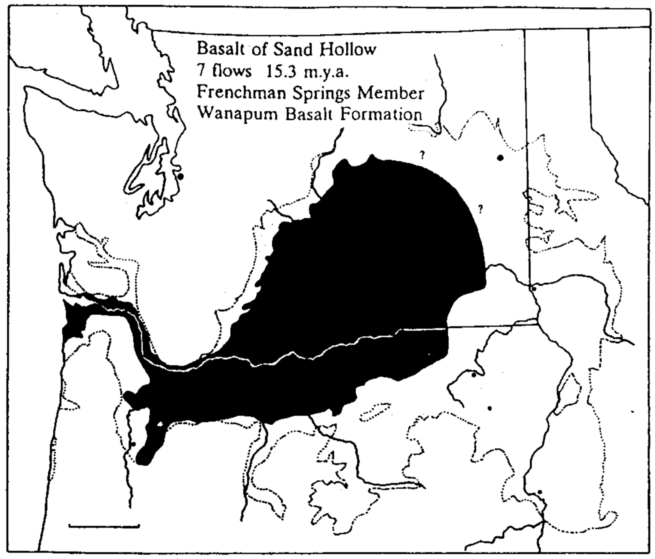
the south, widespread flows of the Prineville and Picture Gorge basalts in the Deschutes and John Day valleys correlate with the Grande Ronde Basalt, but differences in chemical composition of the three lavas distinguish them and indicate separate source magmas.

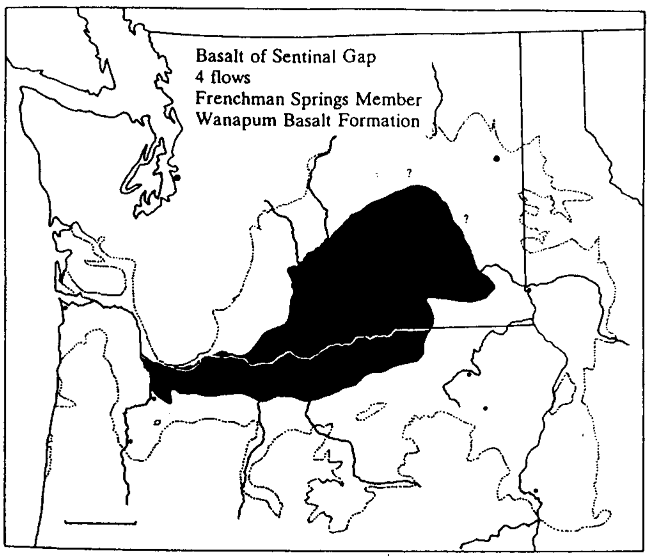
Prior to the extrusion of the Columbia River lavas, the channel of the ancestral Columbia River lay well south of its present course. Individual flows periodically swept into the canyon to plug and disrupt the drainage. As the frequent eruptions subsided, late Miocene and Pliocene compressional folding formed large-scale, east-west wrinkles that confined the river to its present course between Umatilla and The Dalles.

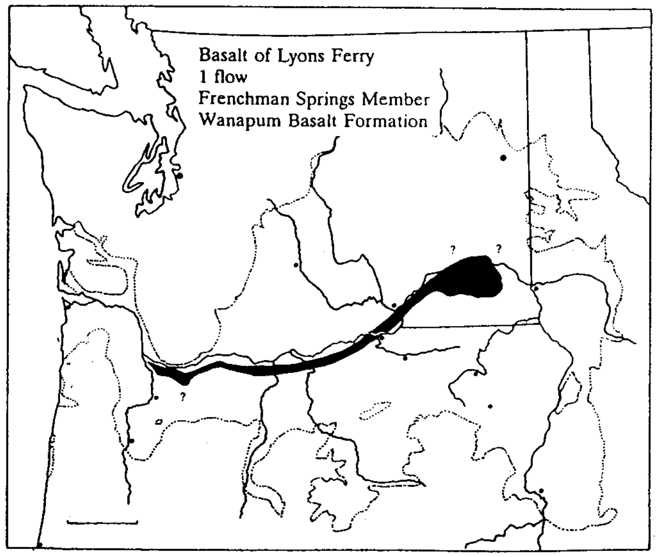


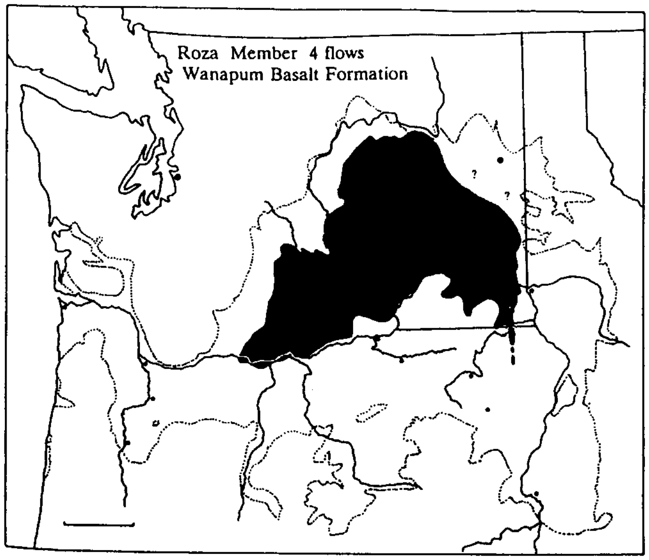
Block diagram across the Columbia River just east of The Dalles

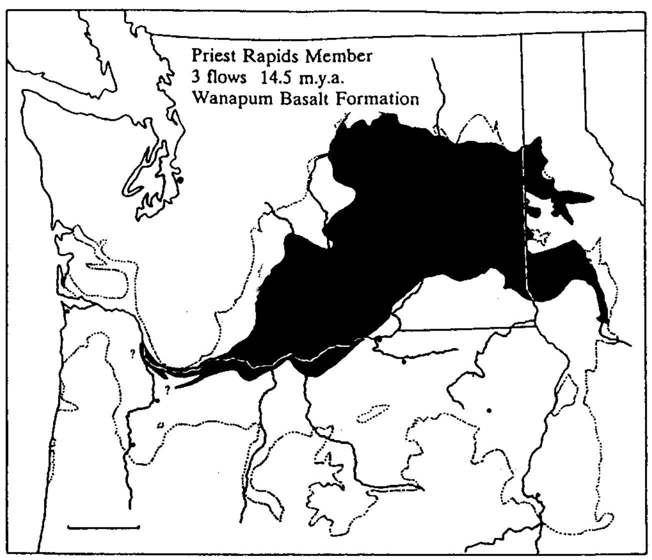

Basalt of Silver Falls
4 flows
Frenchman Springs Member
Wanapum Basalt Formation


Basalt of Sand Hollow
7 flows 15.3 m.y.a.
Frenchman Springs Member
Wanapum Basalt Formation


Basalt of Sentinal Gap
4 flows
Frenchman Springs Member
Wanapum Basalt Formation

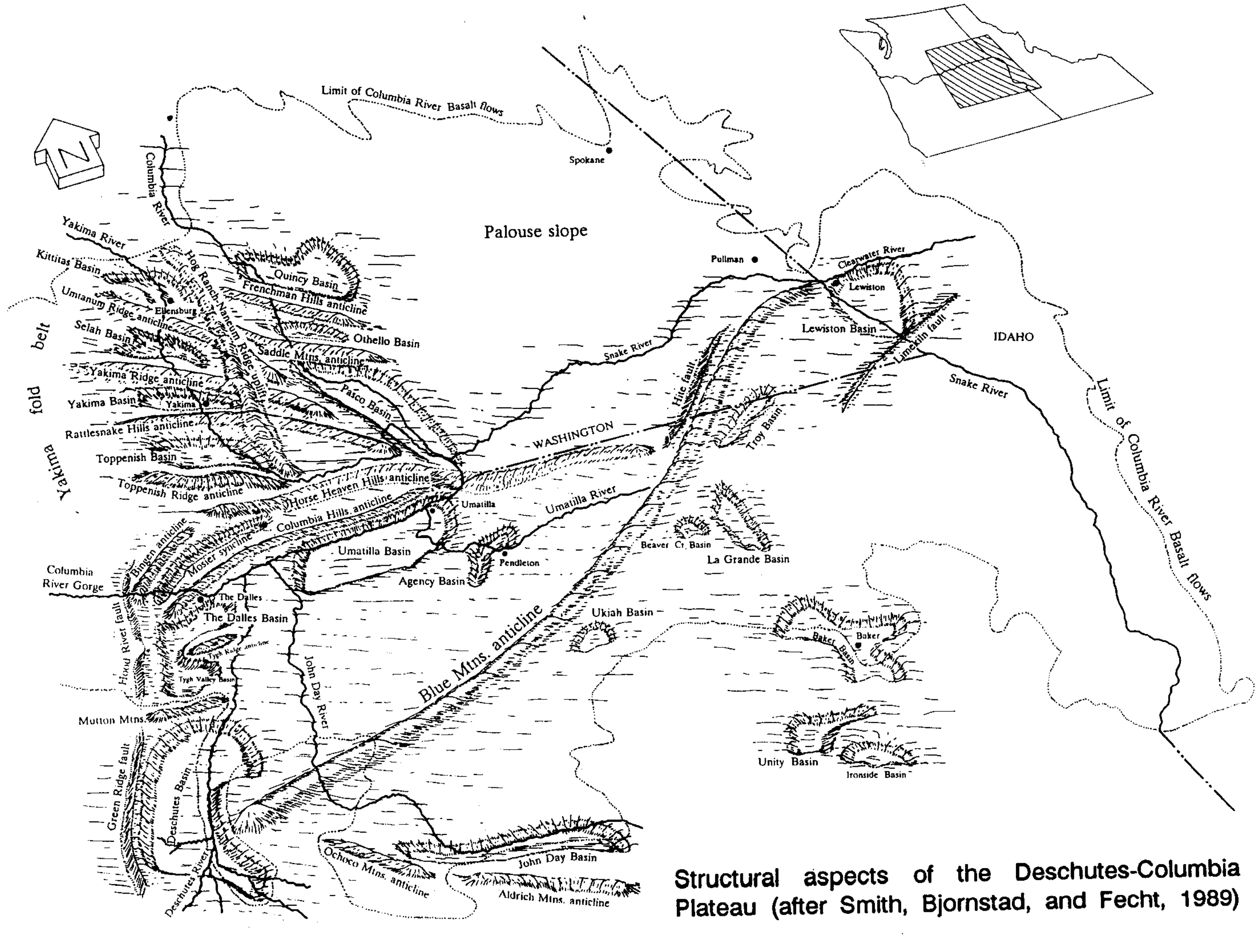

Basalt of Lyons Ferry
1 flow
Frenchman Springs Member
Wanapum Basalt Formation


Roza Member 4 flows
Wanapum Basalt Formation

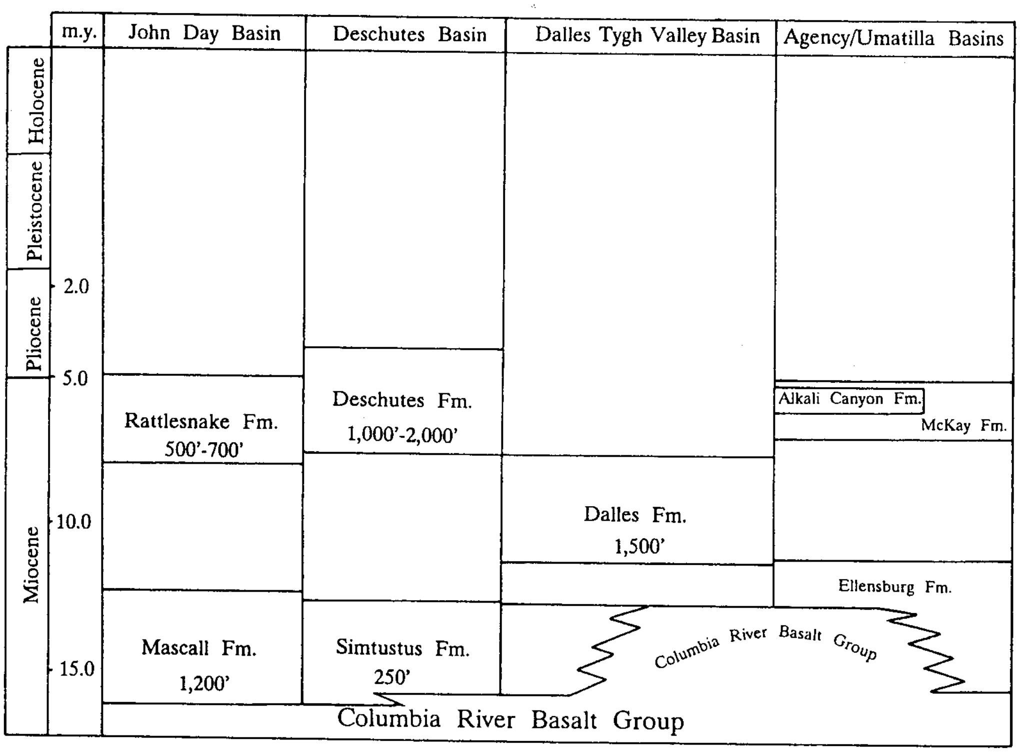

Priest Rapids Member
3 flows 14.5 m.y.a.
Wanapum Basalt Formation

Because of the relative youth and thickness of the Columbia River basalts, rocks immediately below the Miocene lavas are still poorly known. In southeastern Washington small exposures of displaced rocks of the Wallowa terrane imply that this terrane extends far north of its main exposures in the Blue Mountains. Similarly, inliers of the basalt-covered Baker terrane occur well to the west of major exposures in the Blue Mountains. The extent and thickness of Cretaceous rocks as well as Tertiary Clarno and John Day formations, where they disappear under the southern edge of the plateau lavas, may be an indication that they too are much more widespread than presently known. Distinctive rock fragments found imbedded in flows of the Deschutes Formation may have been picked up by the lava as it worked its way to the surface. Although this evidence is tenuous, it suggests that accreted terrane rocks, as old as preCambrian, may be buried beneath the Cascade Range and Deschutes Basin.

Despite the thickness and extent of the lavas, the plateau is not entirely featureless. Over most of its western section, low wrinkles and shallow dimples dot the surface. One of the largest of these is the C-shaped Deschutes basin reaching into the southwest corner of the province. During the early Miocene, the basin received lavas and ash from vents of the Columbia Plateau and adjacent volcanoes of the Western Cascades. Intermittent volcanic activity sent lavas flooding over the vast Deschutes basin, disrupting the flow of streams and rivers. Sediment-choked streams covered 100 square miles of the basin with thin layers of waterlain tuffs, sandstones, and mudstones of the Simtustus Formation. Sedimentation was rapid, and the shallow basin filled with Simtustus deposits up to 250 feet thick. Once designated as part of the Deschutes Formation, volcanic sediments of the older Simtustus Formation are lithologically distinct from the coarse conglomerates of the younger Deschutes. Simtustus rocks are highly significant as they were laid down during emplacement of the Columbia River flows 16 to 12 million years ago.



Structural aspects of the Deschutes-Columbia Plateau (after Smith, Bjornstad, and Fecht, 1989)



Stratigraphy of Tertiary formations of the western Deschutes Columbia Plateau

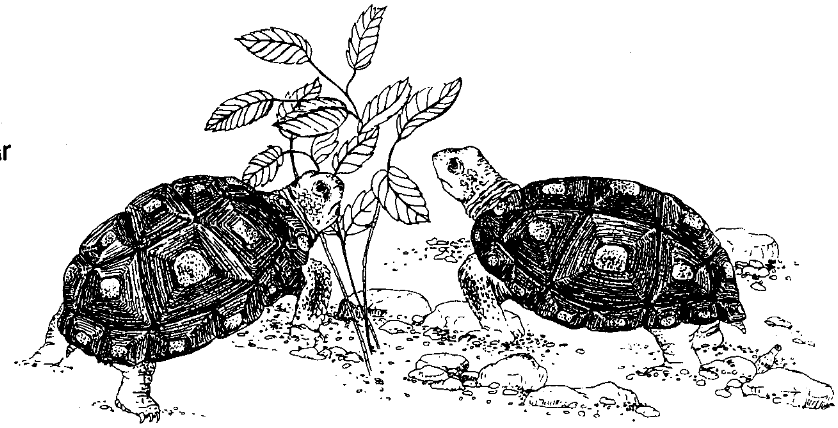
Following a hiatus of approximately 5 million years, volcanics and sediments again poured into the Deschutes basin 8 million years ago from a chain of early Cascade volcanoes, aligned along the western margin of the basin. Voluminous amounts of basalt, andesitic lava, and hot clouds of ash or ignimbrites accumulated up to 2,000 feet on the west side of the basin thinning to 50 feet adjacent to the Ochoco Mountains. Once the northerly flowing ancestral Deschutes River had been overloaded with volcanic debris, it slowed considerably depositing a mixture of volcanic material along the channel and on the adjacent alluvial plain that extended eastward for 30 miles from the Cascades. Blocked by the rising wall of the Cascade graben along the border of the Deschutes basin, the supply of sediments from the west came to an abrupt end 4 million years ago. Deterred by the high Green Ridge scarp, which is composed primarily of ash, lavas, and ignimbrites, streams began to cut down and deepen their channels.

The rise of the Cascade Mountains in the Miocene and Pliocene created a barrier between eastern and western Oregon preventing the flow of warm moist ocean air and subsequently producing the drier climate of today. Prior to the climate change, the plants would have been familiar, but the mammals would have appeared out of place. Oak was a common tree followed by maple, sweetgum, and cherry in the higher elevations with willow and cottonwood in the moister valleys. There was a remarkable absence of evergreens in the upper Deschutes region. Fossils of rhinoceroses, camels, elephants, giant beavers, very small horses, and a three foot long turtle lived here before the climate became more arid.

Pliocene

At this point in time, between 4 and 2 million years ago, a number of small volcanic cones in the upper Deschutes and Crooked river watersheds produced over 200 separate lava and ash beds of Pliocene age throughout the region. Shield volcanoes and cinder cones were built up at Squaw Back Ridge, Tetherow Butte, Round Butte, Black Butte, and Little Squaw Back. Lavas from the Tetherow Butte complex of red and black cinder cones near Terrebonne extended northward covering Agency Plains between Madras and Gateway to depths over 150 feet. The most recent eruptions in the basin were lavas from Round Butte 3.9 million years ago along with the fluid andesitic basalts from the broad low volcano at Squaw Back Ridge 2.9 million years ago. After an initial eruptive period, Round Butte continued to build up, eventually exploding to subside with the formation of two small summit cones. With a pleasing symmetrical profile, Round Butte was the site of Indian ceremonies and is still regarded as a sacred site. Little Squaw Back and Black

Four million year old Pliocene sediments near Arlington yielded the carapace of a 3-foot long land tortoise.



Butte, large shield volcanoes on either side of Green Ridge, probably erupted 3 to 1/2 million years ago. The 6,436 foot andesite cone of Black Butte is the highest in the area.

Pleistocene

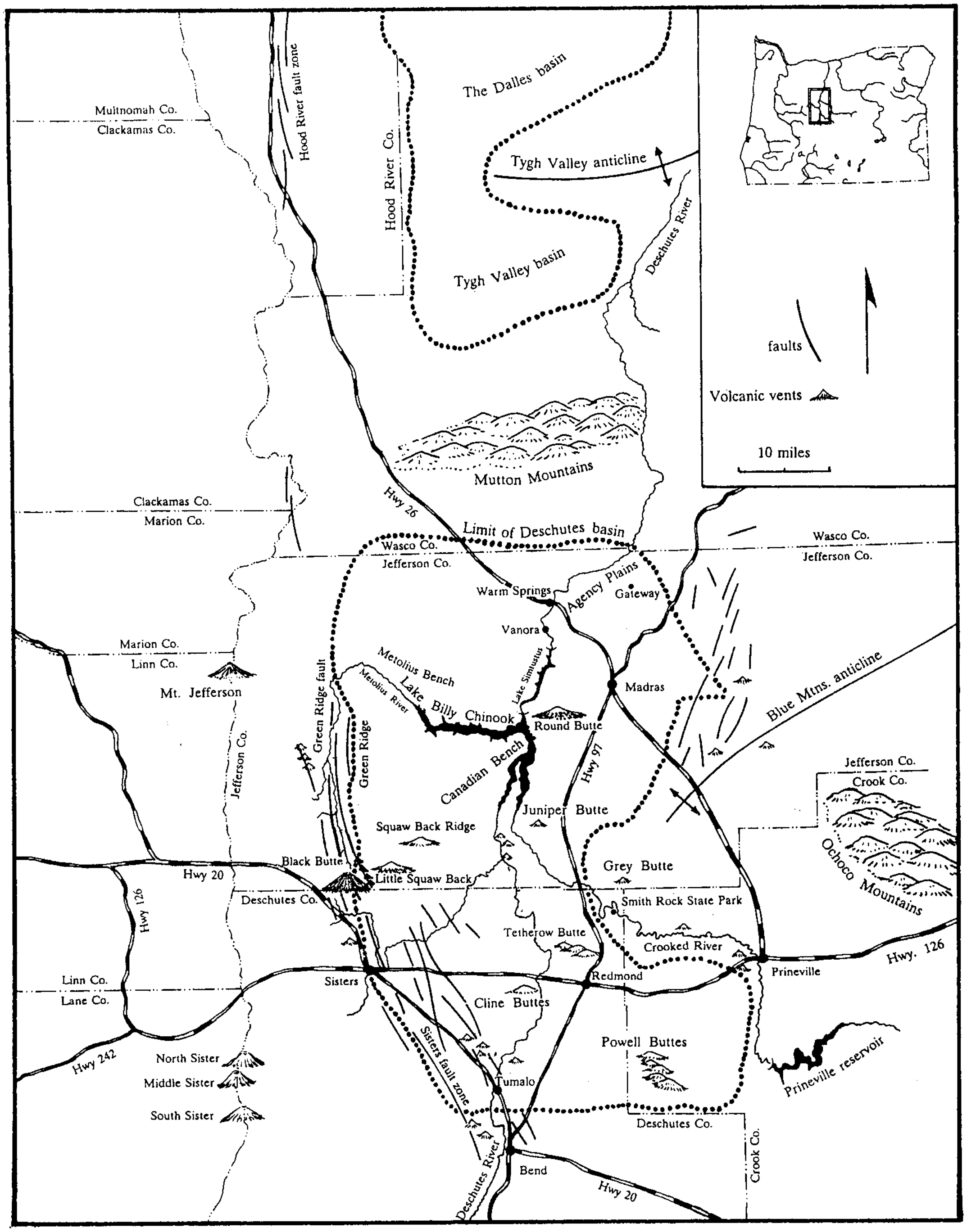
The plateau experienced the last phase of volcanism 1.6 million years ago when early Pleistocene eruptions from local vents plugged the Metolius, Deschutes, and Crooked River canyons with basalt. The most extensive of these numerous flows originated near Newberry crater, filling the Crooked River canyon to depths of 800 feet in places, while an intracanyon basalt pouring into the Metolius River valley formed a pronounced bench 600 feet above the present river level. Within the last million years, however, river waters have been able to reestablish their previous channels completely by cutting around the succession of intracanyon flows. The basalts have been reduced to islands midstream or isolated steep cliffs plastered to the older sedimentary and volcanic layers that make up the main canyon walls.

The Ice Ages of northern Oregon were a time of ice build up and repeated catastrophic flooding. Pleistocene continental glaciers advanced as far south as British Columbia and northern Washington infringing on the Columbia River drainage. Glacial ice temporarily plugged the Clark Fork River, a branch of the Columbia River in Montana, resulting in a glacial lake which drained as numerous separate floods. When the dammed up water was suddenly released, it spread through the Idaho panhandle and southeast Washington to reenter the Columbia at Wallula Gateway. After scouring eastern Washington, millions of gallons of flood water continued down river to complete the final sculpting of the Columbia Plateau. Reaching elevations of about 1,000 feet, the floods removed talus and soil from large areas along the river and covered existing gravel bars with coarse flood-borne material and erratics. On both sides of the gorge from Wallula Gap to The Dalles, flowing water backed up and spread out to create Lake Condon. The lake waters reached the John Day River valley to the south as well as Maupin on the Deschutes where large boulders carried in by icebergs were dropped as the ice melted. Such boulders are common southwest of Arlington, many marking the shoreline of the ancient lake.

Frequent successive flooding left gravel, sand, and silt in the valleys and basins along the Columbia gorge. A thick, structureless, buff-colored Wasco silt, in the vicinity of Moro and Grass Valley, is similar to the Portland Hills Silt. Near Ordinance and Boardman, a large area of unconsolidated sand has been reworked by winds to form dunes. Pleistocene vertebrate fossils are present in the blowouts which reach an elevation of about 600 feet and probably represent fill in the Columbia River valley during high waters. Terraces along the river at The Dalles are composed of gravels that also coincide with flooding stages.

Structure

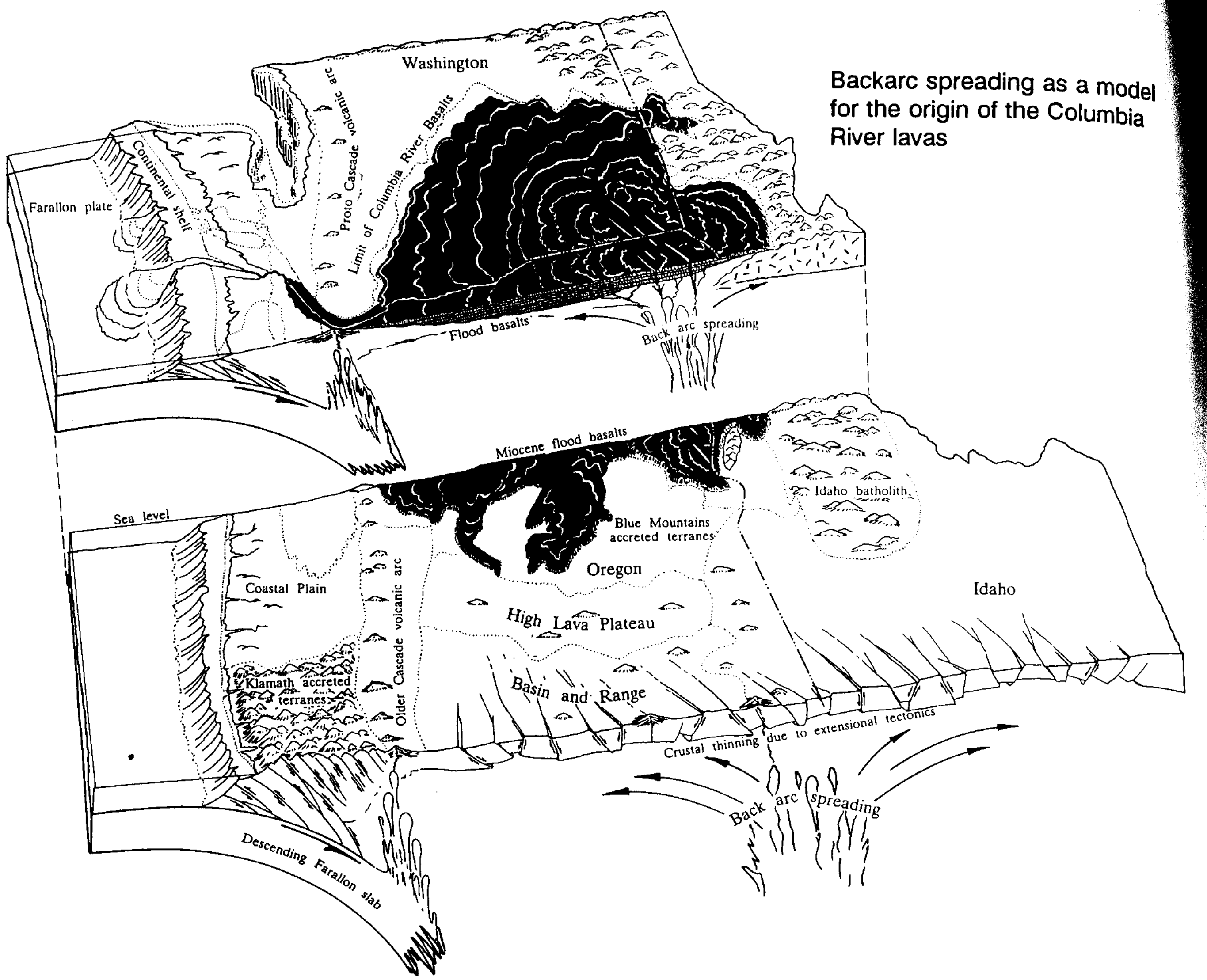
The tectonics and geologic history of the Deschutes-Columbia Plateau relate closely to the movement of the earth's crustal plates, which brought about structural changes throughout the province. The evolution of the plateau has been divided into three phases that took place 17 to 10 million years ago, a second interval between 10 and 4 million years ago, and occurrences over the past 4 million years. During the first stage, tensional stresses from apparent backarc spreading on the North American plate produced extensive north-south fractures in the southeast corner of the plateau and resultant massive lava flows of the Imnaha Basalt. As the eruption continued, new vents



Major geographic and structural features of the Deschutes-Columbia Plateau (after Smith, Bjornstad, and Fecht, 1989)

appeared further north, and the entire plateau was tilted to the northwest by uplift along the Idaho batholith. This tilting allowed the later Grande Ronde flows to extend northward into central Washington and enabled them to reach the Pacific Ocean by way of the Columbia gorge. With as much as 36,000 cubic miles of Grande Ronde basalts being erupted, the crust at the center of the plateau at Pasco, Washington, began to fail and collapse downward to create a basin over three miles deep.

Concurrently, the deformation of the plateau caused minor folding over the Columbia basin and pro-

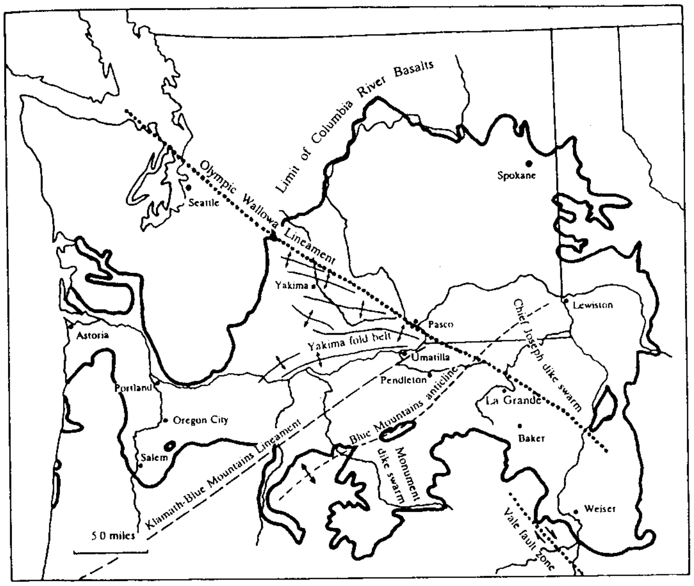


Backarc spreading as a model for the origin of the Columbia River lavas

duced the northeast-southwest trending Blue Mountains anticline or arch. Where the Columbia River bisects the central plateau, a number of surface folds run east-west, corresponding to north-south compression. The Columbia River follows one of these wrinkles as it traverses the axis of a major downwarp, the 160-mile long combined The Dalles-Umatilla basins from Wallula Gap to The Dalles. Further east, the Blue Mountains anticline turns north at Meacham, Oregon, to merge and run parallel to the Klamath-Blue Mountains lineament. In Washington, the Columbia Hills and hills of Horse Heaven anticlines follow The Dalles-Umatilla syncline to intersect the Hite fault just south of Milton-Freewater.

Beneath the plateau, major structural features or lineaments converge. These extensive features can be seen in aerial photographs, but they are not obvious at ground level, and what caused them is uncertain. The Klamath-Blue Mountains lineament runs across the state in a southwest by northeast direction, intersecting the Olympic-Wallowa lineament near Wallula Gap on the Columbia River, while the Olympic-Wallowa lineament runs southeast by northwest from Puget Sound across Washington through the Oregon Blue Mountains to the Idaho border. Cutting directly across the Olympic-Wallowa lineament, the Hite fault system trends southwest by northeast.

With phase two between 10 and 4 million years ago, the spreading direction of the Pacific plate rotated 25 degrees clockwise to a more southwest by northeast direction. At this time intense compression produced a series of east-west wrinkles in southcentral Washington and in the vicinity of the Columbia River. Most of the visible folds in plateau lavas along the Columbia, including the Yakima fold belt, Horse Heaven anticline, and Columbia Hills anticline, are related to this



Major structural features of the Deschutes-Columbia Plateau

phase of deformation. Additional uplift of the Blue Mountains anticline, stretching, faulting, and thrusting in the Blue Mountains and John Day region were also part of these tectonic events.

Over the last 4 million years, the plateau was subjected to continual but subdued north-south compression. Cascade volcanics to the west changed in composition, became localized along a narrow archipelago, and greatly intensified. These conditions persisted until faulting began to lower the volcanoes into a graben along the western border of the Deschutes basin. On the eastern flank of the Cascade graben, the Green Ridge scarp is a well-defined fault zone. The Green Ridge belt appears to merge with the Tumalo fault zone to the south which in turn converges with the Walker Rim and Brothers fault zones at Newberry caldera. The Green Ridge and Tumalo fault zones provided avenues for escaping lava and ash between Bend and the Metolius River valley.

Mining and Mineral Industry

Because of its volcanic character, the Deschutes-Columbia River Plateau has not been an area of extensive mining. Along the Deschutes River 6 miles west of Terrebonne, diatomite was mined commercially from a quarry beginning in the late 1950s and continuing until the deposit was exhausted. The diatomite here was up to 67 feet thick, and the layer has been cut through by the Deschutes to expose the strata on both sides of the valley. The soft white material is easily distinguished from the surrounding tuffs, sands, and lavas.

Diatomite, or diatomaceous earth, is composed of the capsule-like skeletons of microscopic, single-celled glassy aquatic plants. Their abundant presence indicates an ancient lake bed once existed here in the late Miocene or early Pliocene. Flourishing in the fresh waters, diatoms build up a layer of skeletons on the bottom of the lake by the millions. Absorbing as much as 300 percent of its own weight, the lightweight opaline diatomite is porous, fireproof, resists chemicals, and is mined for use as cat box filler, to filter drinking water, in swimming pools, and in chemical laboratories.

Geothermal Resources

Geothermal potential for the Deschutes-Columbia River Plateau is moderate to low, similar to that of the Blue Mountains province, although across the river in Washington well waters have recorded high temperatures. At Warm Springs, above The Cove Palisades State Park, the Confederated Tribes of the Warm Springs Indian Reservation operate a resort built around the mineral springs discovered here in 1855. The natural waters flow from Clarno basalts at 140 degrees Fahrenheit and smell somewhat of hydrogen sulfide.

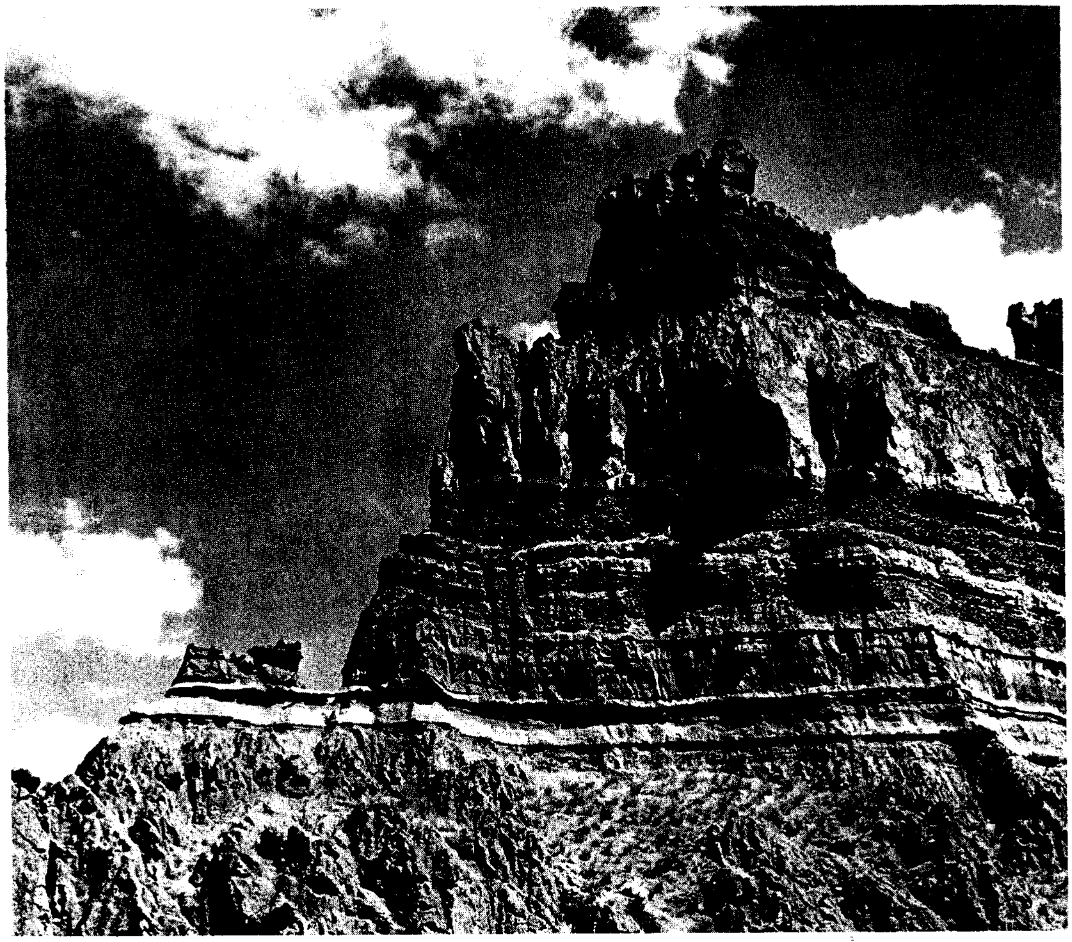
Features of Geologic Interest

The Cove Palisades State Park and the Deschutes Canyon

By persistently cutting downward for millions of years through layers of rock, the Metolius, Deschutes, and Crooked rivers have produced deep gashes in the flat Deschutes-Columbia River plateau to expose 15 million years of geologic history in a 1/2 mile thickness of lavas, volcanic ash, and sand. Once these three rivers merge about 10 miles west of Madras in Jefferson County, the main branch of the Deschutes continues another 80 miles to enter the Columbia River.

Two miles above this juncture, a secluded spot, protected by steep canyon walls, was known as "The Cove" by settlers in the early 1900s. The construction of two dams in this section, the Pelton Dam in the late 1950s to back up river waters into Lake Simtustus and Round Butte Dam in 1964, forming the 3-arm Lake Billy Chinook, changed the configuration of The Cove. The Cove Palisades State Park, originally composed of 3,620 acres when it was purchased as for parkland in 1940 and 1941, now encompasses 7,000 acres.

The geologic history in the park and Deschutes canyon begins in the middle Miocene when the massive lava flows of the Columbia River basalt filled most of the ancestral river canyon to The Cove Palisades park. These lavas originated from fissures in northeast Oregon and southeast Washington and covered vast

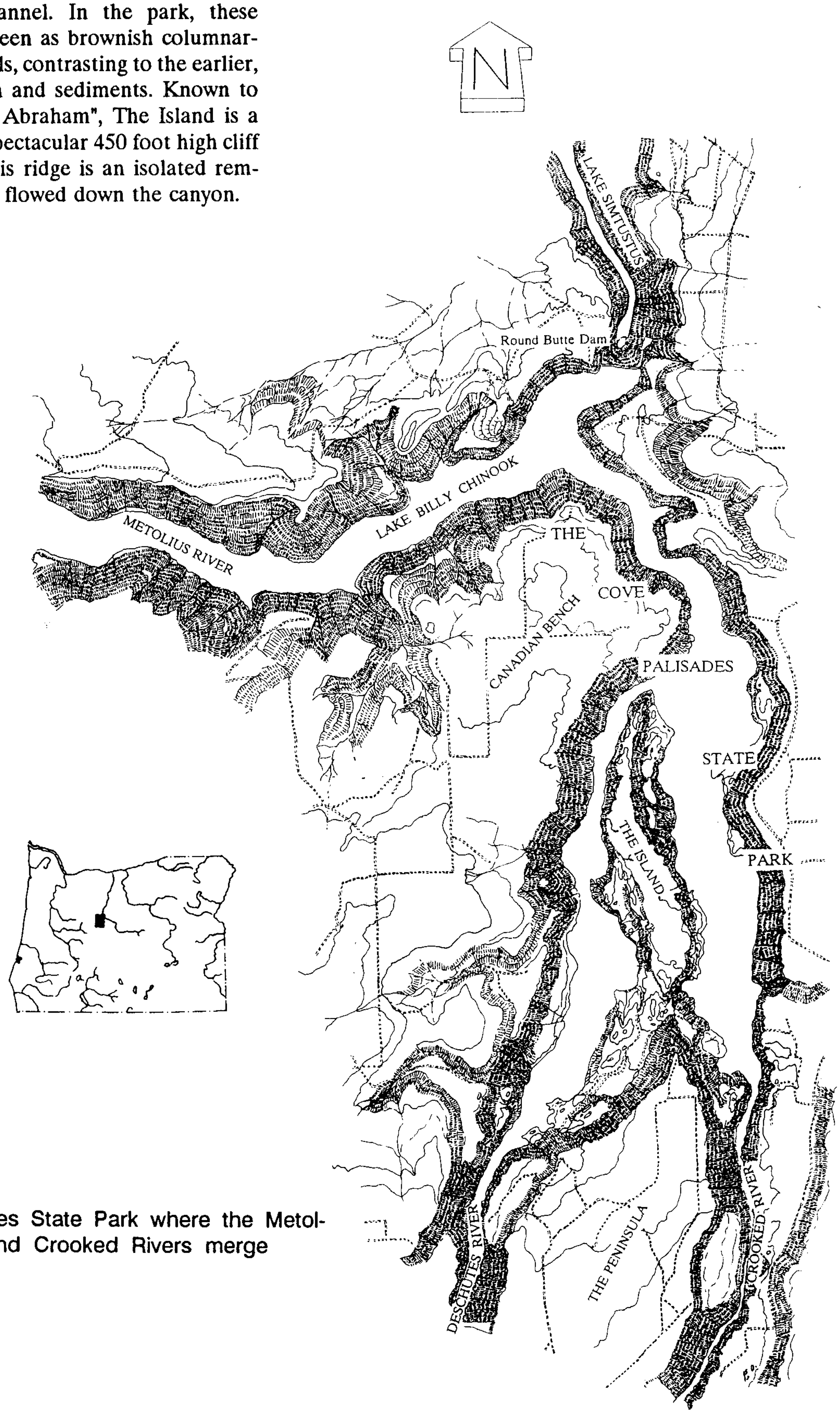


"The Ship" at The Cove Palisades State Park is composed of tuffaceous Deschutes beds capped by rimrock basalt. (Photo Oregon State Dept. of Transportation)

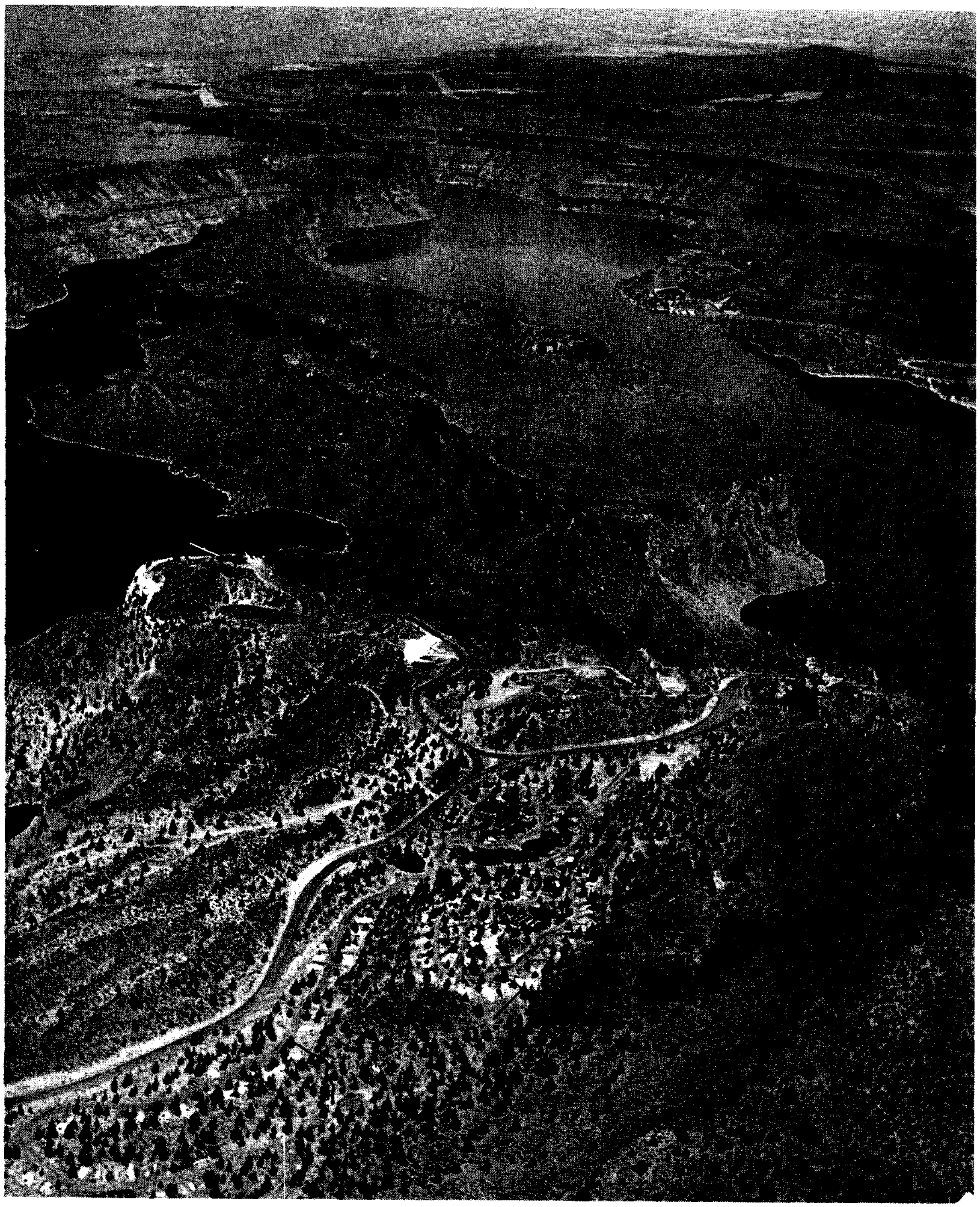
areas of eastern Oregon. Layered between the basalts are sediments laid down by the river waters that were impeded by the volcanic debris. Events during this time are recorded in the canyon walls by rocks on the east rim of Lake Simtustus.

After sucessfully cutting through these basalts for 7 million years, the ancient Deschutes river was once again inundated when Cascade volcanoes began to fill the channel with volcanic debris, ash, and cinders, blocking the waterflow and creating lakes in places. Mixed in with this volcanic material are silt, sands, and gravels carried by the Deschutes as it continued to work at eroding these new obstructions. Most of the yellowish-brown sands and black basalts seen in the canyon walls were produced during this interval from 8 million to 4 million years ago. Distinctive ignimbrite layers are common between the river sediments and lavas. Ignimbrites develop when hot air-borne ash falls to cool as a glassy layer. At The Cove Palisades park an ignimbrite comprises the distinctive white prow of "the ship", one of the scenic features, while sedimentary layers of the Deschutes Formation compose the narrow neck of the isthmus between the two rivers at the south end of The Island. The Peninsula is made up of Pliocene and Pleistocene lavas extruded 2 to 3 million years ago from local vents. Smaller amounts of lavas covered low spots in the valley and diverted the ancient streams and rivers.

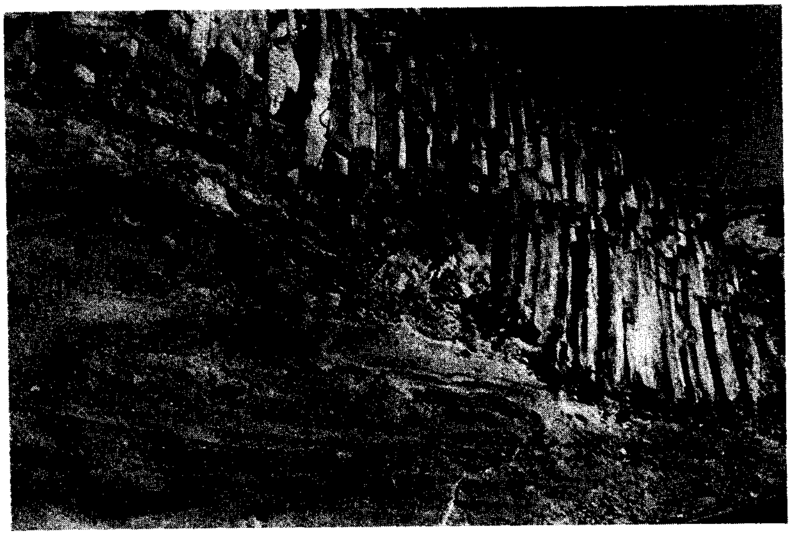
Once this eruptive activity had ceased, the river could concentrate its energy renewing and deepening its channel, which followed the same path as it does today. In a final volcanic event beginning 1.6 million years ago, hot liquid lava poured into the Crooked River, entering the canyon upriver near O'Neil. This lava, from vents at the base of Newberry Volcano, flowed for miles downstream from that point, filling the canyon. At least 15 separate flows inundated the canyons as far as Round Butte in the park before coming to a halt. After moving such a distance, the lavas had cooled somewhat to become thick and sluggish. In the narrows here, a dam was built up by successive layers of basalt temporarily blocking the river. Eventually, however, water opened a gap through the lava dam, carving its path into the former channel. In the park, these intracanyon flows can be seen as brownish columnar-jointed basalt along the walls, contrasting to the earlier, lighter-colored beds of ash and sediments. Known to pioneers as the "Plains of Abraham", The Island is a flat ridge which rises as a spectacular 450 foot high cliff in Lake Billy Chinook. This ridge is an isolated remnant of the last lava which flowed down the canyon.



The Cove Palisades State Park where the Metolius, Deschutes, and Crooked Rivers merge



The Island, at the confluence between the Crooked River on the right and the Deschutes River on the left, is a remnant of a Pleistocene intracanyon flow of basalt. (Photo Oregon State Dept. of Transportation)



Intracanyon flow of columnar Deschutes Formation basalts over a valley cut into ash and cinders at the entrance to The Cove Palisades State Park. (Photo Oregon Dept. of Geology and Mineral Indus.)

The filling of the Deschutes Canyon by the waters impounded behind Pelton and Round Butte dams had unusual side effects. As the lakes filled and the local groundwater table rose, many new warm springs emerged. These thermal springs include 14 in Willow Creek canyon alone. Water temperatures of the springs average around 60 degrees Fahrenheit, which is slightly warmer than most other thermal springs in the region. The presence of the springs has also triggered a dramatic change in the modern flora in the immediate vicinity.

Balanced Rocks

John Newberry, on a railroad exploring expedition to Oregon in 1855, examined the Deschutes area in great detail, recording his trip in copious notes. One of his discoveries was a group of precariously balanced rocks on the north-facing slope of the Metolious River just before the river enters Lake Billy Chinook. The balanced rocks of this striking phenomenon, weighing over a ton each, are perched atop tapering pinnacles 20 to 30 feet high. The rocks, resembling the top knots of Easter Island statues, are more massive and greater in diameter than the pillars which support them. Composed of volcanic basalt and interbedded sedimentary siltstones and sandstones of the Deschutes Formation, the columns are the product of differential weathering. Erosion rapidly removed the softer lower layers and left the resistant cap, which armors the striking columns that stand out in relief. Close by, another group of balancing rocks, named Button Head Rocks, are not as high or as massive.

Metolius Springs

One of the swiftest flowing and shortest rivers in the west, the Metolius begins with waters gushing from the springs at the base of Black Butte to form an "instant river". Situated in the southwest corner of Jefferson County about 30 miles northwest of Bend, Metolius Springs are at the junction of the Western Cascade province, the High Lava Plains province, and the Deschutes-Columbia Plateau. The springs issue from two openings at the foot of Black Butte about 200 yards apart, merging after a short distance to flow northward. Total output from the springs measures 45,000 gallons per minute, and the water temperature is a chilly 48 degrees Fahrenheit.

Geologic events associated with the origin of Metolius Springs began with block faulting. Tension along a north-trending fault caused a block to drop down forming the graben valley of the Metolius. The high Green Ridge fault scarp along the eastern side of the valley blocked the flow of surface water and channeled it toward the north and around the end of the ridge creating an ancestral Metolius River. About 500,000 years ago, eruptions from vents along the fault escarpment built up Black Butte cone straddling the Metolius Valley and covering the ancient river drainage. The waters which once flowed above ground now percolate through sands and gravels in the old channel beneath the volcano before they reappear above ground as Metolius Springs.

Basalt slabs are balanced atop pinnacles of Deschutes Formation volcanics on the Metolius River near Lake Billy Chinook (photo courtesy Oregon State Highway Department).

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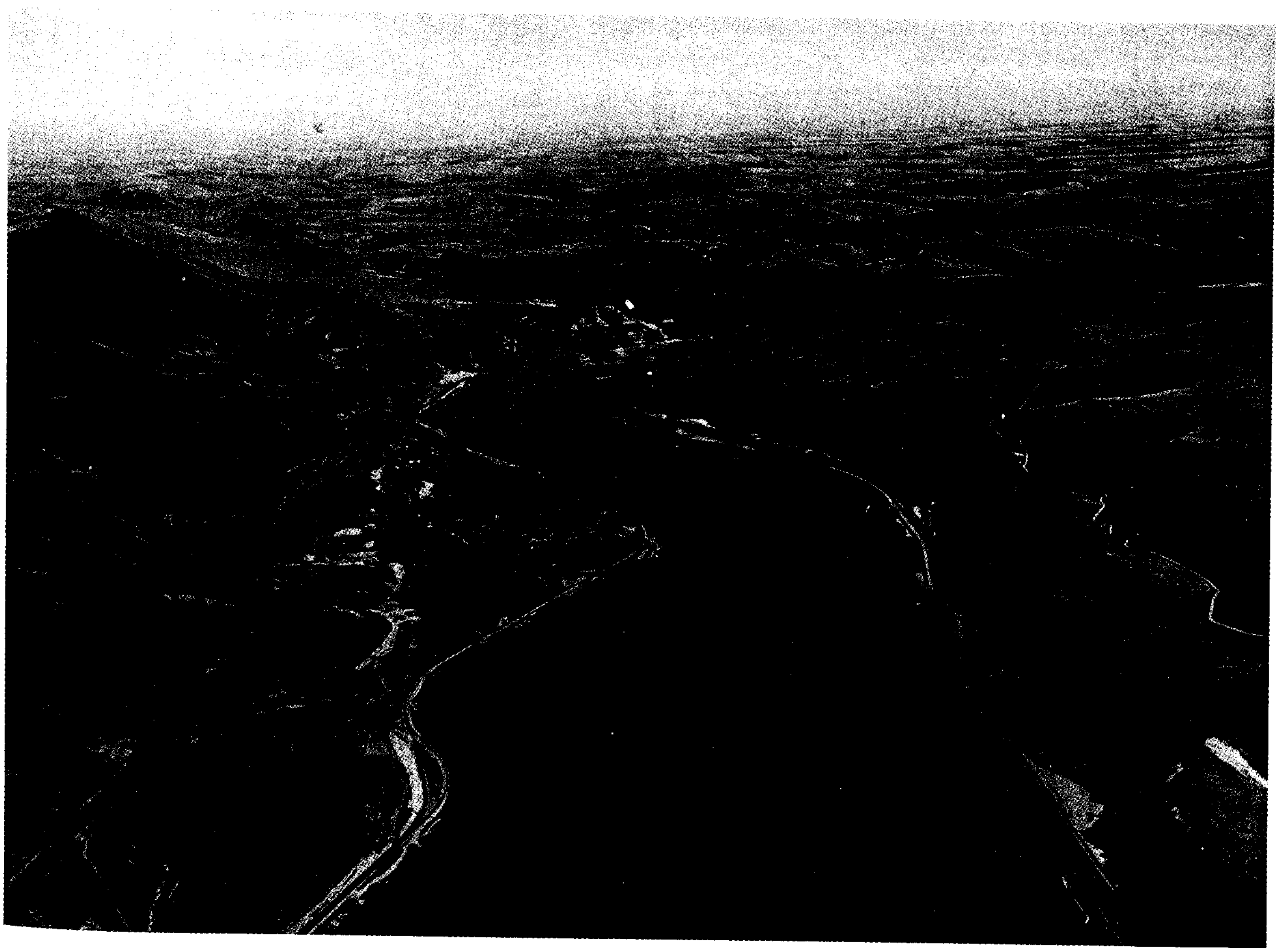

At Biggs Junction, Oregon, the Columbia River cuts through a thick succession of the Miocene Columbia River lavas [photo courtesy Oregon Department of Transportation].