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GEOLOGIC TOUR OF COVE PALISADES STATE PARK NEAR MADRAS, OREGON

By N. V. Peterson* and E. A. Groh**

Introduction

When you drive through the Madras region on U.S. Highway 97, you see a gently rolling plain dotted with low hills and flat-topped buttes. Since the plain appears to extend westward uninterruptedly to the foothills of the Cascade Range, little would you imagine that between you and the mountains lurk three awesome canyons, totally invisible until you nearly reach the brink. Three rivers -- the Deschutes, the Crooked, and the Metolius -- have cut these gashes into the plain and have laid open for observation a sequence of remarkable geologic events. The place where the three rivers join to make one canyon marks the general location of the Cove Palisades State Park (figure 1).

Cove Palisades State Park encompasses Round Butte Dam and its reservoir, Lake Billy Chinook. The 7,000-acre park features picknicking, camping, and boating facilities on the shore of the lake and scenic viewpoints on the canyon rims. The park is an excellent place to see 10 million years of geologic history.

The purpose of this report is to present the geologic background of the park area in a nontechnical way (assisted by a short glossary of terms), and then to outline a geologic motor tour of the park by means of descriptive text, photographs, cross sections, and maps. The self-conducted tour starts at Madras, makes 12 designated stops, and ends on the far side of the park in the canyon of the Deschutes River, a total distance of about 25 miles.

Location and Access

Cove Palisades State Park lies about 10 miles west of Madras (figure 2), the seat of Jefferson County. Madras, with a population of about 2,000, is the main commercial and distribution center for the surrounding agricultural area. Two U.S. Highways intersect at Madras. U.S. 26 leads northwestward toward Mount Hood and on to Portland. In the opposite direction, this

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highway goes southeastward to Prineville and on to eastern Oregon. U.S. 97 crosses the state north and south from Washington to California. The park is easily accessible by good paved roads from Madras and other junctions along U.S. Highway 97 south of Madras. Inside the park, road signs direct the traveler to the various recreation sites and viewpoints.

History and Development of the Park

The Madras area of Jefferson County began to be settled about a century ago, and favored fishing locations and places for relaxation were soon discovered in the deep canyons to the west. One of these places was on the banks of the Crooked River about 2 miles above its junction with the Deschutes. This secluded spot, sheltered by canyon walls, came to be known as "The Cove."

Public and private development through the years improved the accessibility of The Cove, first with roads from Madras and Culver, on the east side, and later with bridges across the Crooked and Deschutes Rivers and a road connecting with Grandview and Sisters on the west. A small hydroelectric plant was built at The Cove in 1912 and was enlarged in 1923 to provide power for the communities of Madras, Prineville, and Redmond. Even a peach orchard was cultivated at The Cove, because the climate is quite mild at the bottom of the canyon.

In the late 1930's and early 1940's, the Oregon State Highway Commission, which had recognized the recreational potential of the area, acquired through purchase and lease agreements from public and private holders some 7,000 acres of this canyon region. After World War II, trails and camping facilities were built and the area was officially named "Cove Palisades State Park."

All of this was to change, though, for in 1960 construction of Round Butte Dam began on the Deschutes River just below the mouth of the Metolius. This rock-fill dam has raised the water level nearly 400 feet above the bottom of the canyon. The old Cove Palisades State Park and the adjacent hydroelectric plant are now under 200 feet of water. Through agreement with the State Parks and Recreation Division, the Portland General Electric Co., owner of the dam, provided for a move of the park facilities to a location about a mile to the southwest on the Deschutes River side of the Peninsula. After the dam was completed, the reservoir created a three-armed body of water which is named Lake Billy Chinook for a Warm Springs Indian guide who accompanied Captain John Fremont in early-day explorations of Oregon. The geologic map (plate 1) and also figures 1 and 2 show most of the over-all extent of Lake Billy Chinook.

Once the lake was available, other additions were made, and the park now has an overnight camp area offering 87 trailer sites and 94 campsites with utility facilities. Three day-use areas provide parking, boat launching, picknicking, swimming, and other recreational accommodations.

Figure 1. Aerial view looking south toward Lake Billy Chinook and Cove Palisades State Park. Round Butte Dam is in the foreground. At the left, the Crooked River and Deschutes River arms of the lake stretch southward. Metolius River arm branches to the right.

A marina concession extends services of boat rental, a restaurant, and sundry supplies. The outstanding fishing, boating, and other accommodations, together with its scenic attractions, make Cove Palisades State Park one of the most desirable of all the Oregon parks.

Within the park area a viewpoint observatory and museum, built by Portland General Electric Co., perches on a cliff overlooking the Round Butte Dam and Lake Billy Chinook. It offers downstream vistas of the imposing Deschutes Canyon and presents information on central Oregon wildlife, Indian artifacts, and construction of the dam. Picnicking facilities are also provided. The observatory is open daily during the summer vacation months and on weekends during the spring and fall. The hours are from 10:30 a.m. to 7:30 p.m. Should the observatory be closed, a short walk to the cliff edge will give you an excellent view of the canyon and dam.

The summit of Round Butte is also a part of Cove Palisades State Park. A paved road to the top of this shield volcano connects with the road from Madras to the Round Butte Dam viewpoint. It has the highest elevation within the area and its summit offers a magnificent panorama of the Deschutes basin, High Cascades, and surrounding country.

Geologic History

The geologic history so dramatically displayed in the walls of the canyons at Cove Palisades State Park tells the story of the past 10 million years. But if you drive to the top of Round Butte, you will see in the surrounding mountains a record of events going back as much as 50 million years.

Early history

Beginning in the Eocene Epoch (about 50 million years ago), numerous volcanic eruptions covered the region with predominantly andesite* lavas and tuffs*, and in some places sediments were washed into shallow basins. These rocks, named the Clarno Formation*, compose the distant Ochoco Mountains on the eastern skyline and also make up part of the Mutton Mountains to the north of the park.

In middle Oligocene time (about 30 million years ago) a new episode of volcanism began to emit tremendously explosive eruptions which continued into early Miocene time (about 25 million years ago). These eruptions threw dacite* and rhyolite* ash and pumice fragments high into the air to fall out over the terrain in thick deposits which later consolidated* into the red, green, and buff-colored tuffs of the John Day Formation. Some of the highlands visible from Round Butte, such as Gray Butte,

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* Words followed by an asterisk are defined in the Glossary of Geologic Terms on page 168.

Juniper Butte, Grizzly Mountain, and part of the Mutton Mountains, were at this time active volcanoes that contributed to the John Day Formation.

In middle and late Miocene time (20 to 15 million years ago) great floods of basaltic lava poured over the eroded surface of Clarno and John Day rocks. These basalts*, named the Columbia River Group, are exposed at the Pelton damsite a few miles down the Deschutes canyon from Cove Palisades State Park.

All three formations -- the Clarno lavas, John Day tuffs, and Columbia River basalts -- are probably "basement rocks" beneath the rocks exposed in Cove Palisades State Park (see cross sections, plate 2, page 162)

Pliocene Epoch

The story of Cove Palisades State Park as revealed in its canyon walls begins in the Pliocene Epoch, which dates back about 10 to 12 million years. At this time, volcanism began building the Cascade Range from north to south across Oregon. Basalt and basaltic andesite lavas erupted from vents to form a series of shield volcanoes. Volcanoes of this type receive their name from the similarity in shape to a warrior's shield lying with the rounded, or convex, side up. Round Butte, situated in the park area, is typical of a small shield volcano. The shield volcanoes of the Cascade Range were much larger, however, and were fed by more vigorous sources of magma*. Numerous lava flows radiating from central vents, and from parasitic vents on the flanks, resulted in huge volcanic piles which coalesced and overlapped, forming the base for the present High Cascades.

Westward-flowing streams were forced to seek north or south courses in order to reach the sea. Thus the ancestral Deschutes River and its tributaries became established. While the Cascades were building, earth movements were causing a slow sinking of the land surface in what is now the middle Deschutes basin, including the area of Cove Palisades State Park. Erosion, the ever-present process of wearing away the rocks, was providing the detritus from the Cascade shield volcanoes for fill in the basin. Airborne volcanic material, such as ash and cinders, carried by the prevailing winds, contributed also. This debris, with minor amounts eroded from the John Day highlands, and many thin lava flows, accumulated over the basement rocks to a thickness of 1000 feet or more. These rocks are called the Dalles Formation. They are exposed in the canyons of Cove State Park and are designated as QTd on the geologic map, plate 1.

Dalles Formation

The Dalles Formation in the Madras region was named for similar deposits at the lower end of the Deschutes River and along the Columbia River near The Dalles.

Most of the sedimentary beds in the Dalles Formation were laid down

in either a river floodplain or a shallow lake environment. They are composed of light- and dark-gray layers of siltstone, sandstone, and conglomerate*. In many places cross bedding is revealed by finer laminations at various angles to the main layering. Crossbedding is characteristic of stream sediments deposited by torrential flood waters.

Numerous basaltic lava flows are interbedded in the Dalles Formation. These lavas came from vents within the basin, and some may have streamed in from the flanks of the growing Cascades. The lava flows undoubtedly dammed and/or diverted the ancestral Deschutes River, developing small, temporary lakes where fine silt and clay were deposited in quiet waters, forming lenses of thinly laminated beds; many examples of these lake-bed deposits are now exposed in the river-canyon walls. The lavas can also be recognized in the canyon walls as more resistant dark-brown layers with prominent columnar jointing*.

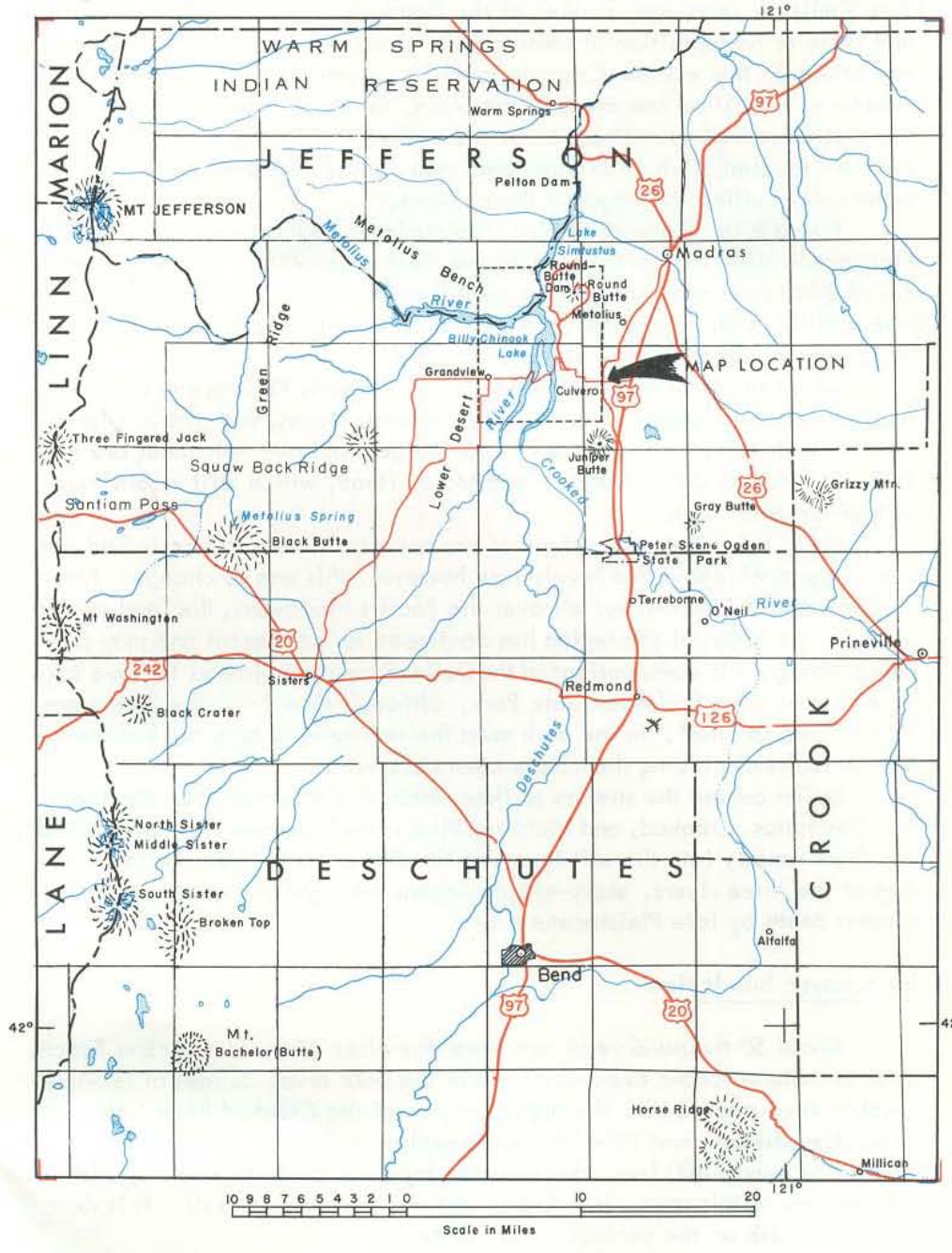
Eruptions in some of the Cascade volcanic centers became more explosive during the latter part of the Pliocene Epoch. Andesitic, dacitic, and rhyolitic ash and pumice were blown into the air, falling out over the basin. Much of the fragmental product also accumulated around the vents and, mixed with periodic lava flows, built the type of volcanoes known as composite cones.

These huge Pliocene volcanoes probably discharged some of the ash-flow tuffs found interbedded in the Dalles Formation in the park area. Ash flows occur when gas-charged magma erupts so rapidly from a volcanic vent that it flows out with great mobility as a suspended mixture of ash, pumice fragments, and gas. Ash flows are estimated to travel at speeds as high as 100 miles an hour, and some spread over hundreds or even thousands of square miles of terrain. The mixture, on coming to rest, tends to fuse or weld together from retained heat and action of the gases. The resulting rock is called an ash-flow tuff, or sometimes a welded tuff. In thick ash flows the inner portion may fuse so completely that it resembles a lava flow. These devastating eruptions occurred numerous times throughout the deposition of the Dalles Formation.

The growth of the High Cascades eventually raised a barrier across Oregon which prevented warm, moist coastal air from moving eastward. The climate of the Pliocene became drier, although not to the degree it is now. The forests took on a modern aspect (Chaney, 1956). The most abundant tree, according to fossil evidence north of the park, was the aspen, but willow, cherry, cottonwood, and box elder were also present.

We probably would feel at home with the vegetation of the Pliocene were we to be transported back by "time machine" to the ancestral Deschutes basin. Perhaps not so with the animals of the time. Although no fossil bones have been found in the park area, fossils found elsewhere in the Dalles Formation indicate that animals such as rhinoceroses, giraffe-camels, hippopotami, elephants, bear-dogs, giant beavers, and pony-sized horses lived in the central Oregon countryside.

Figure 2. Index Map of Cove Palisades State Park.



Pleistocene Epoch

At the end of the Pliocene Epoch or the beginning of the Pleistocene, 2 or 3 million years ago, sinking of the Deschutes basin gradually ceased, and little or no deposition or erosion took place. Then local volcanic vents, and others in the eastern Cascade foothills, erupted basaltic lavas which coalesced and filled low areas in the plain, forming a basalt capping over the Dalles sediments. These lavas are called the Rimrock basalt in this article (labeled QTrb on the geologic map, plate 1), since they characteristically outline the edges of the canyons.

Round Butte is one of the local volcanic vents that was active in early Pleistocene time; it contributed to the Rimrock basalt in the park area. Round Butte continued to build its shield, eventually culminating in explosive activity with the formation of two small summit cinder cones (indicated by pattern on QTrb of geologic map, plate 1).

Along the crest of the Cascade Range, in early Pleistocene time, explosive volcanism began to build lofty composite cones, and glaciers formed high on their flanks. Examples of these large glaciated volcanoes are the Three Sisters, Mount Jefferson, and Mount Hood, which still retain much of their original form.

Up to this time, the surface of the ancestral Deschutes basin had not been very much above sea level; now however, this was to change. Not only in central Oregon, but all over the Pacific Northwest, the land started to rise. Elevation of the region has continued to the present and may still be occurring. No deformation* of the Dalles Formation appears to have taken place in Cove Palisades State Park, although elsewhere the beds were folded* and faulted*. In the park area the sedimentary beds are horizontal and no faults displacing them have been observed.

Uplift caused the streams to flow faster and to erode deep channels. The Deschutes, Crooked, and Metolius Rivers, their courses now entrenched*, cut down rapidly into the soft layers of the Dalles Formation. At the junction of the three rivers, steep-sided canyons were gouged nearly to their present depth by late Pleistocene time.

Intracanyon basalt flow

About 50 thousand years ago, near the close of the Pleistocene Epoch, a remarkable volcanic event occurred in the park area. Surges of red-hot basaltic lava poured into the upper canyon of the Crooked River, flowed miles downstream, and filled the steep-walled valleys in the park area to a depth of nearly 800 feet. Because the lava was contained wholly within the canyons in this area, it is known as the Intracanyon basalt. It is designated as Qib on the geologic map, plate 1.

By the time the lava reached Cove Palisades State Park it was beginning to cool, and in the narrow canyon of the Deschutes, about 4 miles

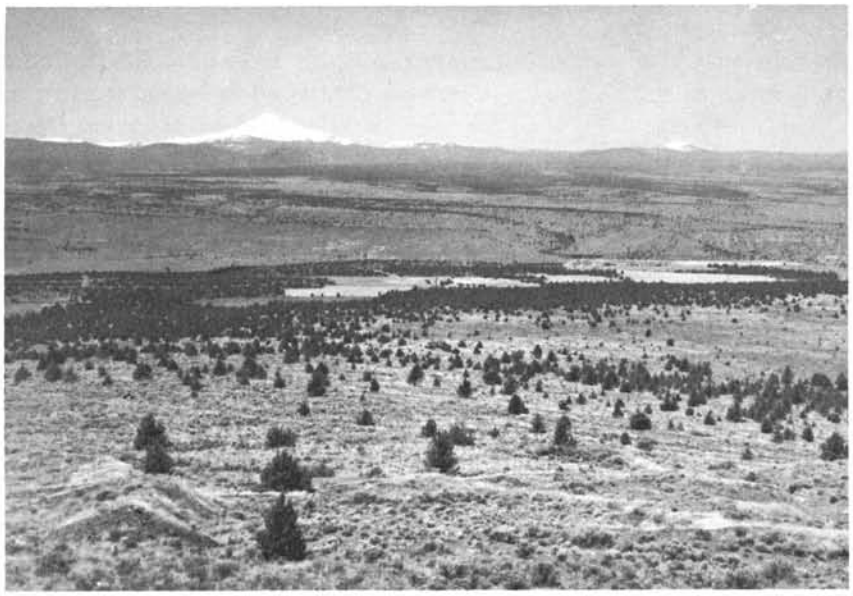
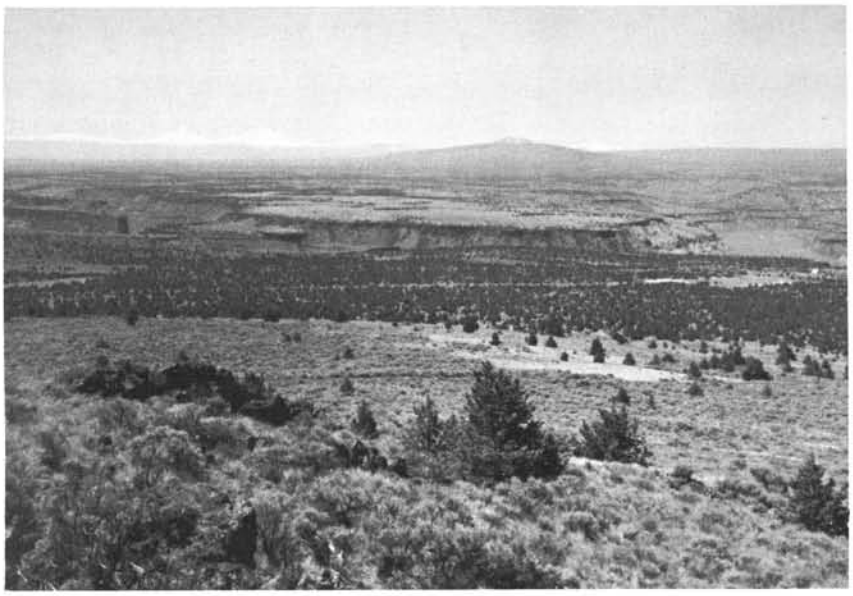


Figure 3. View to the west taken from Round Butte summit. Mount Jefferson to the left and Olallie Butte to the right.

Figure 4. View to the southwest from the summit of Round Butte. Peaks are, from right to left, Mount Washington, Black Butte behind Squaw Back Ridge, Black Crater, North and Middle Sister, South Sister, and Broken Top. The canyons of Crooked, Deschutes, and Metolius Rivers are in the middle distance.



below the mouth of the Metolius, the sluggish end of the flow piled up to form a dam. As the river of molten rock continued to be fed from its source, its level rose behind the lava dam and backflowed 8 miles up the Deschutes and at least 4 miles up the Metolius canyon. Here, too, a damming took place and, with continued supply, a great pool of lava rose and flooded the canyon area to within 200 feet of the rims. The volume of lava filling the canyons is approximately one cubic mile.

From where did all this lava come? Surprisingly, the source was far to the south of Cove Palisades State Park. From its terminus, the Intracanyon flow can be traced up the Crooked River for 27 miles to the point where it entered the canyon 1.5 miles west of O'Neil (shown on figure 2). And yet, the probable source lies another 32 to 35 miles south in the vicinity of Horse Ridge, about 16 miles southeast of Bend, making the total distance traveled by this amazing lava flow come to more than 60 miles!

The erosive force of running water is not easily thwarted, and after the emplacement and cooling of the Intracanyon lava flow, the rivers proceeded to wear it away. The Deschutes and Metolius Rivers cut new gorges through it. Even the Crooked River, whose canyon contained the greatest obstruction, succeeded in carving its way completely through the Intracanyon basalt, reaching its original depth.

In Cove Palisades State Park, wedge-shaped remnants of the Intracanyon lava lie against the walls of the former canyon. The brownish-black, columnar-jointed basalt is in sharp contrast to the lighter colored Dalles beds. At the Island, also a remnant of the Intracanyon lava, the sheer basalt cliffs rising 450 feet above the lake give some idea as to the tremendous volume of lava that once filled the valleys and the powerful forces of erosion that have cut steadily through it.

Landslides

Most recent of the geologic processes at work in the canyons of the park has been landsliding -- the downward movement of large masses of earth and rock under the influence of gravity. Oversteepening of the canyon walls through downcutting by the rivers triggered these movements in the park area. The landslides (indicated by Qls on the geologic map, plate 1) occurred long before Round Butte Dam was built to form Lake Billy Chinook, which in effect has stopped river erosion. These masses of earth and rock now slope gradually out toward the center of the lake and represent fairly stabilized areas where the park facilities have been developed.

A Geologic Tour of the Park

Forearmed with the general geology given in the preceding section, the area should now be visited in its natural setting. The 12-stop tour will start at the top of Round Butte for an over-all view of the surrounding

geology; then proceed to points on the canyon rim; and, finally, move down into the canyons themselves.

As previously mentioned, the park and its several viewpoints can be reached from road junctions south of Madras, but it is preferable to start from Madras in order to take in the whole tour.

Whether you come into Madras from the north or the south, you will see a large green Highway Department sign pointing west toward Round Butte Dam and Cove Palisades State Park. Follow the sign and, in about 0.8 mile, turn right and follow Belmont Lane. A little more than 2 miles farther, the road dips into Dry Canyon. Where it climbs out on the other side of this valley there is a good exposure of cross-bedded, gray sandstone of the Dalles Formation. A short distance farther west, a road cut exposes the basaltic lava flows of Round Butte; you are now on the gently sloping flanks of this volcano whose summit, slightly to the left, is the immediate objective; coming abreast of the north side, you can see exposed in a quarry the dark-red cinders composing the cone.

About 7.5 miles from the starting point in Madras, the road descends a long grade. A power line crossing the road ahead warns of an approaching junction; turn left, as the signs indicate, and proceed south another 1.7 miles. Here is the entrance to the Round Butte Dam viewpoint, which will be by-passed for the moment to continue straight ahead for nearly a mile. At this spot turn left and drive up to the top of Round Butte.

STOP 1: At the top of Round Butte, 700 feet above the surrounding plain, the view is truly magnificent. More than 100 miles of the Cascade Range with its snow-capped volcanoes is spread along the western skyline. Mount Jefferson is closest and due west (figure 3). To the left, Three Fingered Jack, ravaged by glaciation, appears on the horizon, followed by Mount Washington with its pointed spire. The symmetrical cone, Black Butte (figure 4), shows only its apex, being obscured by Squaw Back Ridge. Next to be seen are Black Crater and the imposing peaks of the Three Sisters. Finally, in the distance is the glaciated cone of Broken Top, and to the left the summit of Mount Bachelor. All of these volcanoes were built during Pleistocene time and those showing the best conical form have been the most recently active.

By turning due south you can see Juniper Butte which, along with Gray Butte and Grizzly Mountain still farther to the left, is made up of John Day tuffs and flows. These buttes and mountains are erosional remnants that mark the main centers of volcanism in the area at that time. The original volcanoes were probably much larger than they are now. In spite of all the workings of erosion, they are still prominent highlands today.

The view from southeast to northeast shows the distant hills and ridges making up the western part of the Ochoco Mountains that continue far to the east to merge into the Blue Mountains of eastern Oregon. The visible mountains are composed mainly of John Day and Clarno Formations.

Figure 5. Looking over Round Butte Dam from the viewpoint observatory. Deschutes canyon and Lake Simtustus are beyond.

Figure 6. Crooked River and Deschutes River arms of Lake Billy Chinook, separated by the Island on the left as seen from the first, or northern, rim viewpoint.

Directly to the north is the large highland of the Mutton Mountains, composed also of John Day Formation rocks along with some of the Clarno Formation. The Mutton Mountains probably represent a large eruptive center which spread a great variety of volcanic products onto the area during John Day time. Mount Adams in Washington is visible, on a clear day, between the Mutton Mountains and Mount Hood.

To the northwest, in solitary splendor, is Oregon's highest peak -- that magnificent volcano, Mount Hood. Typical of the other peaks in the Cascade Range, its lofty cone was formed by the products of explosive eruptions and lava flows from a central vent.

Finally, in completing the circular view of the prominent features from Round Butte, there remains Olallie Butte (figure 3) several miles north of Mount Jefferson. This eroded volcano is capped by a knob called a plug dome, which resulted from the accumulation of viscous lava over the vent in the last stages of eruptive activity.

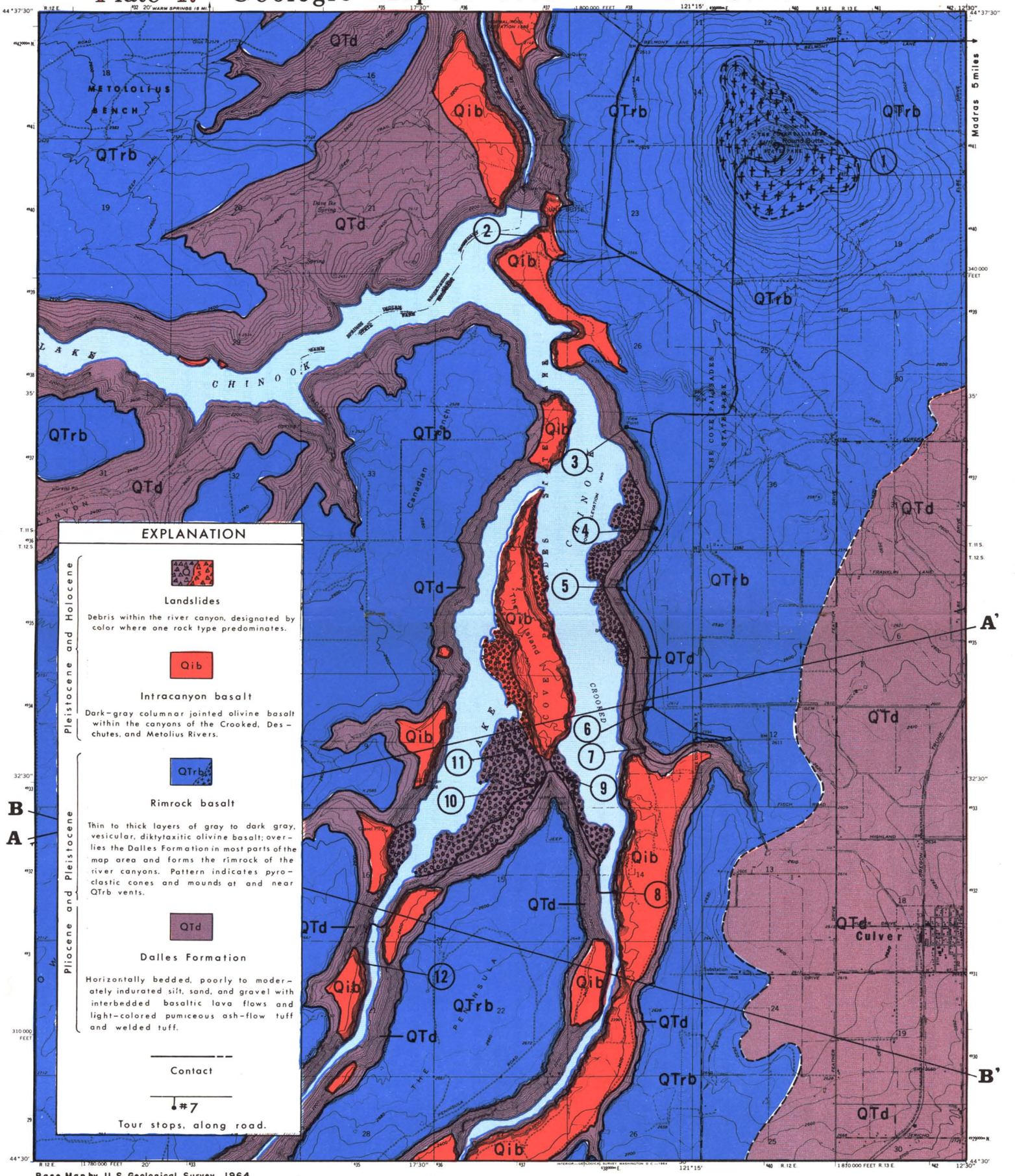
Below, and surrounding Round Butte for miles in all directions, is the plain of the middle Deschutes River basin. Basaltic lavas of Pleistocene age floor most of the basin and, although not well revealed from this vantage point, are cut through by the great canyons of the Crooked, Deschutes, and Metolius Rivers. The dark rims of these lavas sharply outline the excavations in the plain. From this over-all view of the surrounding country, the tour now leads down to the level of the plains and into the canyons below.

STOP 2: After coming down from the summit of Round Butte, turn right at the road junction and return to the Round Butte Dam viewpoint junction, a distance of about a mile, and continue on to the observatory overlooking the dam. Below is the first good view of the Deschutes canyon and the Metolius canyon to the left, now partially filled by the reservoir waters of Lake Billy Chinook. Downstream beyond Round Butte Dam are the still waters of Lake Simtustus backed up by Pelton Dam. A road leading down the right canyon wall to the base of the Round Butte Dam has cut through numerous beds of the Dalles Formation (figure 5). Halfway up, two brownish-weathering interbedded basalt flows are exposed.

Above the west end of the dam there is a wedge-shaped remnant of columnar-jointed basalt of the Intracanyon flow. Its top surface is on a level with the observatory, which also rests on a remnant of the Intracanyon flow. This bench-like surface extends around to a position above the east end of the dam and provides the footing for the powerline towers (figure 5).

STOP 3: The next objective after leaving the observatory is the first of four viewpoints located on the rim of the Crooked River canyon. Proceed again towards the Round Butte junction, turn right, and continue on the paved road for a total distance of 3 miles from the observatory. A small sign pointing to the right directs the way into the low-walled parking area. About 650 feet below is the wide Crooked River arm of Lake Billy Chinook,

Plate 1. Geologic Map of Cove Palisades State Park



Base Map by U. S. Geological Survey 1964

UTM GRID AND 1963 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

OREGON
QUADRANGLE LOCATION

(see page 162 for cross sections)

and to the left (figure 6) the first glimpse of the Island, a large remnant of Intracanyon basalt that separates the Crooked and Deschutes River arms of Lake Billy Chinook. This observation point is perched on the Rimrock basalt at an elevation of nearly 2,600 feet, while the surface of the Island, composed of Intracanyon lava, is 200 feet lower. Upstream in Crooked River canyon small peninsulas jut out into the water (figure 7); these are the tops of several of the landslides previously described under the Geologic History heading. Even the Island has not escaped this type of massive erosion, as shown by a large landslide visible at its center.

STOP 4: The second rim viewpoint is about 0.9 miles farther south on the Crooked River canyon rim. To the northwest, you can see the shore of the Metolius arm of Lake Billy Chinook framed by the Intracanyon basalt (figure 8). To the right, several interbedded columnar-jointed lava flows within the Dalles Formation are well exposed. Also in view is the capping Rimrock basalt, which probably had its source in Round Butte. To the left, across the lake, the landslide of the Island breaks the continuity of the vertical palisade* cliffs (figure 9). Below you is the hummocky landslide mass on which marina parking facilities are situated.

STOP 5: The third rim-rock viewpoint, about half a mile farther south, provides a view upstream into the Crooked River canyon. At this point you can see the vertical walls of the inner gorge cut into the Intracanyon basalt flow that filled the older outer canyon of the Crooked River (figure 10). The top of the Intracanyon flow in the Crooked River canyon matches that of the Island to the right, both having an elevation of about 2,400 feet. Also, from this vantage point can be seen the park entry road grading down to a hairpin turn and then following the level of the reservoir southward.

STOP 6: The most impressive view from this observation point is that overlooking the saddle between the Peninsula on the left and the Island on the right (figure 11). Light- and dark-colored sedimentary beds of the Dalles Formation, including at least two ash-flow tuffs, are exposed at the end of the Peninsula. A rock pinnacle called "The Ship," about halfway down the ridge, is an erosional remnant of an ash-flow tuff layer that caps dark-gray sandstones made of basaltic fragments. Visible through the saddle are the Deschutes canyon and Deschutes arm of Lake Billy Chinook. Benches formed by the Intracanyon flow are seen along the canyon. The lava that poured down the Crooked River pooled at the junction of the two rivers, and backed up into the Deschutes River Canyon.

While at this observation point, look up the Crooked River at the benches of Intracanyon lava; then sweep your view to those in the Deschutes canyon, over to the Island, and down the Crooked River as far as possible. When you mentally connect these features, you can imagine the

Figure 7. Looking up the Crooked River canyon from the first rim viewpoint. The basaltic lava mass of the Island is on the right.

Figure 8. From the second rim viewpoint the shoreline and canyon wall of the Metolius arm can be seen in the distance. The Island is on the left.

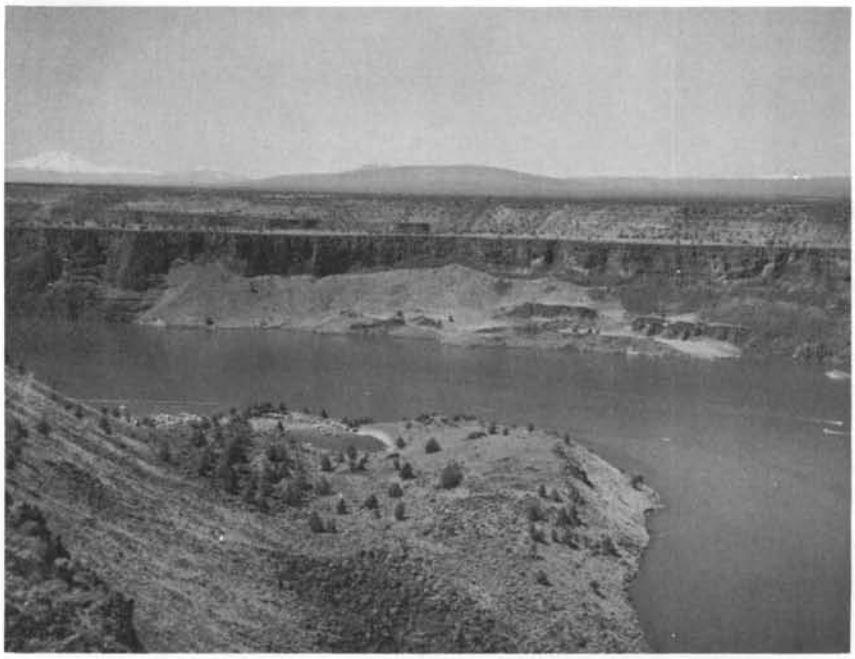


Figure 9. Landslide on the Island as observed from the second rim viewpoint. Marina parking area in foreground.

Figure 10. View south up the Crooked River canyon from the third rim viewpoint. Park entrance road is on the left.

Figure 11. Looking across the saddle between the Peninsula, left, and the Island, right, into the Deschutes River canyon from the fourth, or southern, rim viewpoint.

Figure 12. Contact between Intracanyon basalt on the right and Dalles Formation strata on the left, as seen from upper end of park entrance road.

immense lake of lava which once filled the ancestral Crooked and Deschutes River canyons. This black-crusted lake probably gave off fumes and steam for many years, since such a large volume and thickness of lava must have cooled slowly.

Also, directly below this viewpoint is the location of the former Cove Palisades State Park and the old hydroelectric plant, now drowned beneath some 200 feet of water.

STOP 7: After leaving the last of the rim viewpoints, the road winds about three-quarters of a mile to the junction with the park entrance road into the canyon. Turn right and travel slowly down the grade. On the left are the cultivated and irrigated benchlands on the surface of the Crooked River Intracanyon basalt flow. Various exposures of the Rimrock basalt are on the right. A sharp right turn opens to view the expanse of the canyon and reservoir.

As you descend the main park road into the canyon, you pass the layers of the Dalles Formation, which are well exposed in the road cuts. The top, or youngest, layer is a very light-gray, pumiceous sandstone probably deposited by wind. Next, a small, interbedded basaltic lava flow shows excellent columnar jointing; a buff-colored skin coats the weathered surfaces, but the fresh rock is dark gray to black. Typical of the Dalles Formation is the next lower bed, which is a thick, brown to dark-gray sandstone and conglomerate showing cross bedding.

At this point there is a space for parking to the left. Here, overlooking the nearby canyon wall, there is an excellent exposure of the contact between Dalles beds to the left and Intracanyon basalt to the right (figure 12). The sharp divergence between two types of rock resembles a fault, but is actually a line of contact where the younger lava flow rests against an older erosional surface (an unconformity*). The Dalles beds are freshly exposed along the road cuts to the left. A pinkish-tan ash-flow tuff layer contains lumps of pumice and crops out conspicuously in many places along the canyon walls of the Deschutes and Crooked Rivers.

Continue down the entrance road to the next rock unit beneath the pinkish-tan ash-flow tuff. It is a dark-gray sandstone derived from volcanic detritus. Beneath it there is another ash-flow tuff. It is about 30 feet thick, light gray in color, and contains large lumps of pumice. Next is a pebble-and-cobble conglomerate bed of dark gray color overlying a light-gray volcanic ash layer. Beneath this is another dark-gray pebble-and-cobble conglomerate. From here to the hairpin turn at the bottom of the slope the Dalles beds are obscured by rubble and slope debris of the landslide on which the park facilities are built.

STOP 8: After rounding the hairpin turn, the road follows along the shoreline of Lake Billy Chinook. Roadcuts show sandstones, conglomerates, and ash-flow tuffs comparable to those in the upper section. This is

approximately in the middle of the Dalles Formation, and the age of the rocks is estimated to be about 6 million years. The sheer cliffs of the Intracanyon basalt rise above, and its contact with the layered sediments can be seen in numerous places.

About a mile and a half beyond the hairpin turn, a hill-like mass across the canyon can be seen protruding into the lake (figure 13). This is another landslide which has broken from the walls of the Peninsula behind it. The tilted beds show movement typical of a landslide block.

Just before crossing the bridge over the Crooked River arm of Lake Billy Chinook, the roadway offers an excellent view of the inner gorge of the Crooked River (figure 14). Thick remnants of the Intracanyon basalt stand above the water line on each side, attesting to the river's power to cut directly through this resistant rock in order to maintain its course.

STOP 9: After crossing the bridge, proceed up the road over the back of the landslide previously mentioned toward the saddle between the Peninsula and the Island. Park at the convenient spot available for the first close view of the thick Intracanyon basalts of the Island (figure 15). The palisade cliffs, some 450 feet high, are a good example of a complex cooling pattern in basalt. The curved pattern is due to the ponding, back-flowing, and intertonguing of the lava as it congealed, and the columnar jointing is a result of cooling and contraction of each flow unit.

As you continue over the crest of the saddle, there is an interesting rock on the left side of the road. It is a large basalt boulder displaying petroglyphs which were carved into its surface by prehistoric Indians.

STOP 10: About 500 feet farther along the route, a side road enters from the right. Stop here for a view back toward "The Ship" and a section of the Dalles Formation (figure 16). This is part of the same series of rock layers encountered on the park entrance road. Beginning with the pinnacle of "The Ship," there is a remnant of the pinkish-tan ash-flow tuff; below it is the dark-gray sandstone and, in descending order, the thick, light-gray ash-flow tuff; the dark, sandy conglomerate beds; and, at the bottom, a thin, light-gray volcanic ash layer. The pinkish-tan ash-flow tuff provides us with an excellent "marker" bed for our correlation.

The terrain on this side of the saddle is part of an immense landslide in the Deschutes canyon. This landslide, with the help of a smaller one on the Crooked River side, has produced the gap or saddle between the Island and the Peninsula. The slide is about 2 miles wide, as shown on the geologic map (plate 1). Even though the surface is hummocky, it provides sufficient level land for development of the overnight campground, parking, boat launching, and other recreational conveniences.

STOP 11: Drive northward a short distance down the side road to a parking spot at a pumice pit on the left for the best view of the north end

Plate 2. Geologic cross sections for Cove Palisades State Park

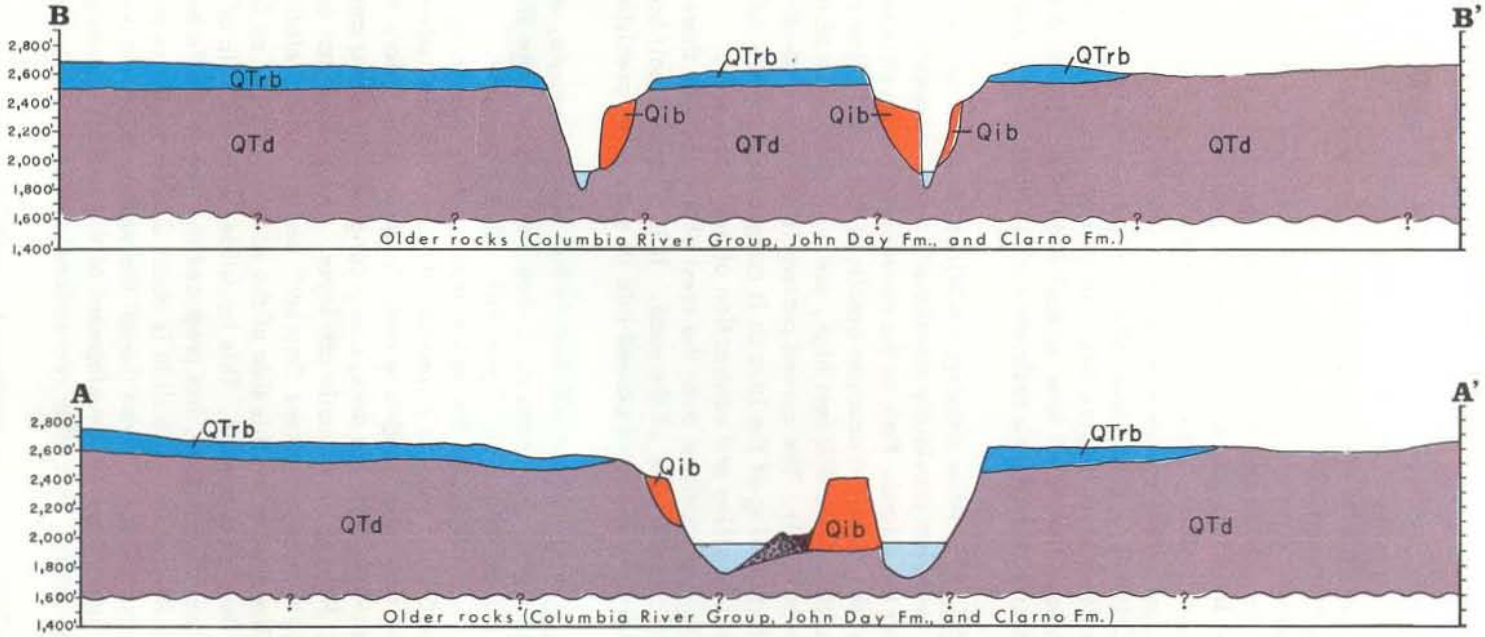


Figure 13. Tilted beds in a landslide seen across the Crooked River arm. The Peninsula is in the background.

Figure 14. The Crooked River gorge from the bridge crossing.

Figure 15. Palisade cliffs of the Island as seen from below the saddle.

Figure 16. "The Ship" stands as a prominence to the left at the end of the Peninsula. The thick, light-gray layer is ash-flow tuff.

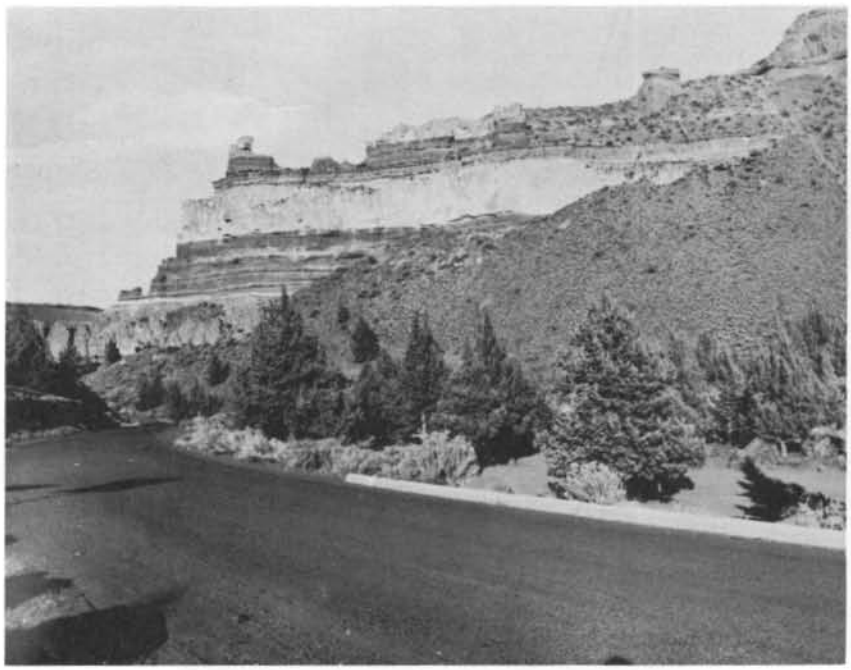
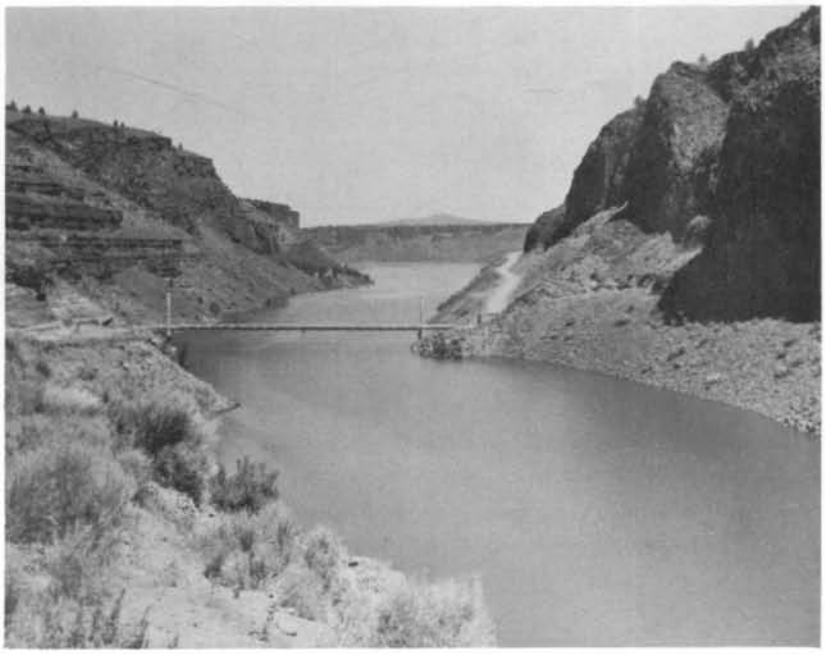


Figure 17. Looking at the northern end of the big landslide in the Deschutes River canyon. On the right is the Island.

Figure 18. The view is northerly down the Deschutes canyon from the first hairpin turn above the bridge. Round Butte is visible in the background.



of the big landslide (figure 17). Here a large section of the thick basalt lavas of the Island has slumped down from the canyon wall, reducing itself to a huge pile of rubble. It is a fine example of the geologic process called mass wasting, a gradual downhill movement of material under the force of gravity, aided by the oversteepening of the canyon wall by the past erosive action of the river.

Return to the main road, turn right, and after reaching the end of the pavement continue over the well-graded gravel road into the steep-walled Deschutes canyon. On the opposite canyon wall sedimentary layers of the Dalles Formation are well exposed. Many beds which are better consolidated and more resistant to weathering than others stand out as ledges. Visible again are the perched wedge-like remnants of the Intracanyon basalt and their unconformable contacts with the underlying Dalles beds.

STOP 12: Cross the bridge over the Deschutes River arm of Lake Billy Chinook, and notice the typical sandy and conglomeratic beds of the Dalles Formation in road cuts. On reaching the first switchback, about a third of

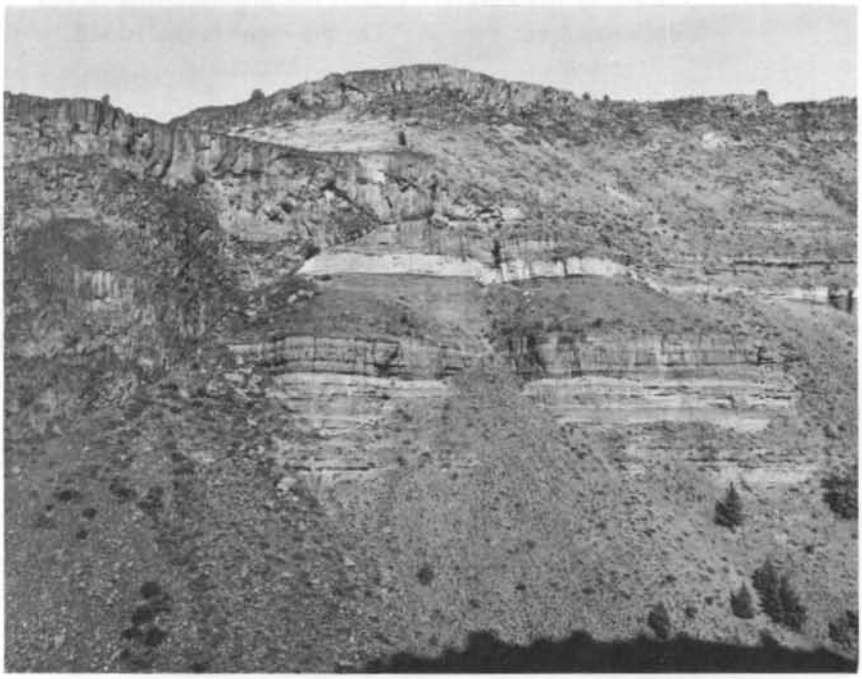


Figure 19. Dalles Formation beds in contact with Intracanyon basalt to the left, seen from the same location as that of figure 18. Light-colored bed slightly above center is ash-flow tuff.

a mile south and above the bridge, stop at a roadside parking strip for a view to the north down the narrowed canyon of the Deschutes (figure 18). On the right and left are massive columnar-jointed remnants of the Intracanyon basalt.

Directly east across from this position there is an excellent view of the contact between the Intracanyon basalt and layered rocks of the Dalles Formation (figure 19). A pinkish-tan ash-flow tuff layer is visible nearly halfway down the canyon wall. It appears to be our favored "marker" bed seen before at "The Ship" and on the park entrance road.

Another unconformable contact of the Intracanyon basalt is visible just above this parking spot. Basalt is lying against gravelly slope wash, which was present on the canyon wall at the time the lava flowed over it. A reddish baked zone at the contact shows the influence of heat from the lava flow.

This ends the geological tour of the Cove Palisades State Park; but we hope that you will follow the tour in reverse on your return trip to the canyon rim and Madras in order to review and remember better the sequence of events that formed this unique geological area.

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Glossary of Geologic Terms

Andesite- Medium- to light-gray igneous rock usually extruded as lava flows but also occurring as fragmental products from release of gases during explosive volcanic activity.

Basalt- Black to gray igneous rock generally extruded as lava flows. Often shows blowholes and is then called vesicular basalt.

Columnar jointing- Shrinkage cracks produced by cooling of a basalt flow, forming a hexagonal pattern on the surface and columns in side view.

Conglomerate- Rounded, water-worn rock fragments, such as pebbles, cemented together.

Consolidated-Compacted or cemented to form solid rock; for example, consolidated sand is sandstone.

Dacite-Light-colored igneous rock found as thick lava flows but more commonly as fragmental products such as ash and pumice.

Deformation-Any change in the original form of a rock mass, such as a movement along a break (fault) or a bend (fold).

Entrench- To erode downward, as a stream cutting a gully or canyon in its former valley.

Fault- A break in rock where one side has moved in relation to the other. The amount of displacement can vary from a few inches to miles.

Fold-A bending of rock as a result of earth pressures. Best seen in layered rock.

Formation-A large and persistent stratum of one kind of rock that can be mapped as a geologic unit.

Magma-The mixture of molten rock constituents and dissolved gases existing at depth. On erupting at the surface, it forms lava flows and fragmental products such as ash, cinders, pumice, scoria, and bombs.

Palisades-A line of bold cliffs, generally composed of basalt and showing columnar structure.

Rhyolite- An igneous rock of light color similar to dacite. Forms very thick lava flows encrusted with the volcanic glass called obsidian. Most often, it is erupted in the form of ash and pumice.

Tuff- Deposits of ash and pumice that have become compacted into rock. Some tuffs are very resistant to erosion. Others are soft and wear down easily.

Unconformity-A surface of erosion, representing a lapse of time, separating younger rocks from older ones. Usually seen as a line in cross section.

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