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GEOLOGIC MAP OF THE PROPOSED PATERSON RIDGE PUMPED-STORAGE RESERVOIR, SOUTH-CENTRAL WASHINGTON

By

R. C. Newcomb

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-653

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GEOLOGY OF THE RESERVOIR AREA

The area here described was proposed by L. L Young (1967) as a site for a multipurpose reservoir to store water pumped from the Columbia River. This investigation concerns largely the factors governing water tightness of the reservoir. The requirement for water tightness is considerably more rigid in a pumped-storage operation than it would be in an on-stream reservoir. For want of any specified limits, the author considered a total of 5 cfs (cubic feet per second) per 1 million acre-feet stored to be the maximum leakage desirable and 10 cfs per 1 million acre-feet stored to be an excessive amount of leakage.

General relations of the main classes of earth materials.—The unconsolidated materials that largely cover the bedrock are important mainly as constructional materials, impediments to construction, and vegetation-supporting soil. The water-holding capacity of the reservoir site is dependent on the bedrock units, the Yakima Basalt, and the interlayered members of the lower part of the Ellensburg Formation, as these units occur beneath the reservoir site and the composite Columbia Hills uplift which forms the southern side of the reservoir.

Stratigraphic and petrologic characteristics of the bedrock.—The top 900 feet of the accordantly layered basalt, with interlayered sedimentary units, is exposed within the area mapped. The layered basalt is estimated to be at least 3,000 feet in total thickness beneath this site. The basalt extends 100 miles or more in all directions—far beyond the basins of the small streams of the reservoir area (Newcomb, 1959).

The basalt accumulated as successive outpourings of highly fluid lava, the outpourings range from 20 to 200 feet thick. A single outpour, or a group of nearly contemporaneous outpourings (a flow), consists of one or several arrivals of fluid lava (flow units), each of which cooled with its individual systems of solidification joints, flowage structures, and gaseous inclusions. An average flow (or flow unit) consists of dense basalt with a vesicular zone 5 to 10 feet thick at the top and several feet of more flinty or glassy lava at its base. It has an overall vertical columnar jointing system. The perfection of this system varies from flow to flow, and within a single flow, between an obscure rude arrangement and a geometrically exact, generally hexagonal, arrangement. Flow breccia, resulting from post-solidification movement of part of a flow, is present but is uncommon. A mixture of pillow lava and palagonite tuff occurs in the lower part of some flows where the lava has moved into water or over wet materials.

The joints are riven and open near the land surface but are progressively tighter with depth from the land surface. At a depth of 50 feet, joint cracks in excavations are tight and some may lack even the characteristic iron oxide stain. At greater depth, zones permeable enough to provide large yields of water to wells are limited to breccia or rubbly basalt that occurs at the top of a few of the lava flows. Zones of lesser permeability that will yield small quantities of water to domestic and stock wells occur in large cracks at the top and bottom of some of the flows. The rocks which have permeability sufficient for the movement of large quantities of water to wells constitute only about 2 to 6 percent of the whole basalt mass.

Most of the successive outpourings of lava were separated by sufficient time to permit the preceding flow to completely solidify before the arrival of the next flow. Some of the flows had been partly covered by soil before the next flow arrived, others had been completely covered by deep soil, and a few had received deep covers of volcanic ash and other sedimentary materials. Each of the top three flows in this reservoir area lies upon such a sedimentary unit.

In the mapped exposures the uppermost sedimentary unit contains a sand or gravel lens in some places, but elsewhere it is essentially all semiconsolidated clayey tuff, silt, and clay. The second sedimentary unit consists only of tuff and tuffaceous silt and clay in the exposures observed. The third sedimentary unit is known in the reservoir area only from the drilling record of one nearby irrigation well (listed below); the interval in which it should crop out in Alder Creek Canyon is covered by colluvium and loess. Except for the few local sand and gravel lenses, the sedimentary units lack the permeability necessary to transmit even small quantities of water to wells.

Structural aspects of the bedrock.—The broad basinal structure of the reservoir site within the eastern part of the Swale Creek-Glade Creek syncline (Newcomb, 1967) is shown in the map and sections, as is also the layered arrangement of the bedrock units. The inherent resistance to water escape downward across the layers is emphasized by the known lack of vertical cross-layer permeability in the basalt flows (Newcomb, 1959) as well as the general impermeability of the sedimentary members.

The vulnerability of the reservoir to leakage along the surficial zone of open joints in the basalt is limited to areas near the dam sites and interbasin rims, because elsewhere the tight basalt below the surficial openings continues upslope well above any contemplated level of water storage.

The erosion of Dead Canyon and Glade Creek valleys has cut through the top basalt flow and into the second basalt flow where the layered bedrock rises southward to the Columbia Hills uplift. Thin zones of relatively low permeability in the top of the second flow in Glade Creek and in the top and lower part of that flow in Dead Canyon may form potential routes for minor leakage around dams located in these declivities. Young (1967) considered it desirable to dike off the Dead Canyon basin along the Dead Canyon-Glade Creek divide just east of Dead Canyon. Such a dike would need a cut-off wall in the unconsolidated materials, whose average depth is unknown but is estimated to be 30 feet, and a grout seal of the surficial part of the top basalt flow.

Fault displacements, such as the one along the north side of the western part of Paterson Ridge, cause the disruption of any horizontal permeable zones in the basalt; also, their shear planes can, in places, offer vertical cross-layer avenues of relatively low permeability. The upward movement on the south side of the Paterson Ridge fault caused the second basalt flow to occur in the ridge escarpment opposite the level of proposed water storage in the reservoir. Minor local zones of permeability at the top and bottom of the second basalt flow may be capable of leading leakage downslope beneath Paterson Ridge and away from the reservoir unless entry to these zones is obstructed by natural or artificial sealing. The downslope drift of debris from the overlying clayey tuff of the uppermost sedimentary unit, as well as the cover of silty loess, may have formed a partial natural blanket over the outcropping ends of permeable zones in the second basalt flow.

Because vertical shear planes in the Paterson Ridge fault would incorporate an impermeable element, as a result of the crushing and smearing of the semiplastic tuffaceous sedimentary members, it is unlikely that this fault would constitute a path of great permeability for descent of reservoir water to lava flows below the second basalt flow.

Occurrence of ground water.—Ground water flows out at springs that occur in the Swale Creek-Glade Creek syncline in Alder Creek, Glade Creek, and Dead Canyon. The entire dry-season flow of Alder Creek, in most years about 1 cfs, rises into the streambed between the northwest edge of the mapped area and the axis of the Alder Ridge anticline. About 0.20 cfs of the water rises into the channel and adjacent bars of channel gravel in sec. 27, T. 5 N., R. 23 E.,[1] and alternately follows the channel and subsurface paths to the vicinity of Sally Spring where a permanent flow of about 0.60 cfs enters the creek. Between Sally Spring and the axis of the Alder Ridge anticline an additional 0.40 cfs adds itself inconspicuously to the creek. Most of this spring discharge is believed to come from the second basalt flow. A few gallons of water per minute emerge from alluvium overlying the top part of this second basalt flow in Six Prong Creek but the water evaporates or sinks into the alluvium (sec. 33 and 34, T. 5 N., R. 23 E.) in the half mile of creek channel leading east to Alder Creek.

The dry-season flow of Glade Creek enters the channel between a small spring near the west line of sec. 21, T. 5 N., R. 25 E., where about 0.05 cfs rises, and the axis of the Canoe Ridge anticline—beyond which a permanent flow of about 0.10 cfs runs in the channel. Though Glade Creek valley is floored only by alluvium, the position of the spring indicates that the water rises from the top of the second basalt flow.

The spring discharges in Dead Canyon are small; the largest (about 0.02 cfs) flows for a few hundred feet in the channel after emerging from bouldery alluvium near the top of the second basalt flow in the southeast corner of sec. 20, T. 5 N., R. 24 E. Each of the other three springs has very small quantities of water and occurs on clayey parts of the alluvium. A very small spring of this latter type occurs one-fourth mile north of the old river channel in Artesian Coulee and is the only discharge of ground water observed outside of the main synclinal basin.

The water wells within the mapped area are all small-yielding domestic or stock wells 150 to 300 feet deep, except for a well or two at Paterson, one of which reportedly yielded 100 gpm (gallons per minute). The wells at Paterson have a natural water level near an altitude of 350 feet, a height that indicates the water is confined. Only two stock wells, one east of Glade Creek (SW¼ sec. 34, T. 6 N., R. 25 E.) and one in Dead Canyon at the northwest edge of the area, are below 500 feet in altitude and within the area proposed for water storage. The best records on strata penetrated by

[1]All land survey designations refer to the Willamette Meridian and Base Line.

drilling are on wells outside the proposed reservoir. Two representative drilling records are given below with stratigraphic designations inserted by the author.

Paterson Village well of Pryor Land Company
[SW¼SW¼ sec. 5, T. 5 N., R. 26 E., altitude 437 ft]
[Drilled by Moore and Anderson, 1964]

Material	Thickness (feet)	Depth (feet)
Sand and gravel	9	9
Top basalt flow:		
Rock, brown	19	28
Rock, gray	68	96
Uppermost sedimentary unit:		
Clay, brown	7	103
Clay, blue	44	147
Gravel and clay	8	155
Second basalt flow:		
Rock, gray	8	163
Rock, brown	22	185
Rock, gray	141	326
Second sedimentary unit:		
Rock, gray, and clay	8	334
Shale, blue	20	354

Casing, 10-inch, set 0–157 feet
Static water level 97 feet (below surface) Sept. 2, 1964
Test pumped 100 gpm with 175 feet drawdown after 6 hours

Smith-McAndrews irrigation well
[NE¼NE¼ sec. 15, T. 6 N., R. 23 E., 3½ miles northwest of the mapped area, altitude 1,045 ft]
[Drilled by Moore and Anderson, 1967]

Material	Thickness (feet)	Depth (feet)
Soil and hardpan	5	5
Top basalt flow:		
Rock, brown, black, and gray	77	82
Uppermost sedimentary unit:		
Shale and clay	29	111
Second basalt flow:		
Rock, black, and gray	175	286
Rock with clay	7	293
Second sedimentary unit:		
Clay, yellow	10	303
Clay, gray, and brown	10	313
Basalt of the Columbia River Group, undifferentiated:		
Rock, brown (water bearing, static water level 101 ft)	38	351
Rock, black, and gray (water bearing 377-405 ft)	139	490
Rock, with green clay (water bearing, static water level 103 ft)	47	537
Clay, green	22	559
Rock, black	15	574

Material	Thickness (feet)	Depth (feet)
Rock, black, and dark brown (water bearing, static water level 77 ft)	9	583
Rock, dark brown (water bearing, static water level 45 ft)	5	588
Rock, dark brown, and black (water bearing, static water level 37 ft)	5	593
Rock, brown, and black (water bearing, static water level 14 ft)	2	595
Rock, black (water bearing, static water level rising progressively to 1 ft)	29	624
Rock, gray	9	633

Casing, 12 inch, set from surface to unrecorded depth, 10-inch liner 268-323 feet, 8-inch liner 440-560 feet.

Summarized, the records of ground water show: (1) The top basalt flow is non-water bearing or may have permeability in places for only very small quantities of water near its base in the lowest parts of the synclinal basin; (2) the second basalt flow in places has low to moderate permeability near its top and base; (3) the interbedded three sedimentary units are non-water bearing and either perch ground water on their tops or depress the level of confined ground water that occurs below their bases; and (4) permeability sufficient to yield large quantities of water to wells in the basalt occurs only at depths greater than 500 feet below the top of the basalt—a situation also found in this rock sequence across the Columbia River in Oregon (Hogenson, 1964; Robison, J. H., written commun., 1969).

Because most of the ground water in the basalt occurs under confined, perched, or confined-and-perched conditions, the concept of water-table levels is only generally applicable (Newcomb, 1969). In synclinal areas along major drainages the main, or regional, water table is taken to be the lowest natural water level in wells tapping aquifers in the basalt. In places, such as the Columbia River valley, this main water table is a few tens of feet above the natural river level. In structural basins (like the reservoir area) above the level of the main drainage, the pressure levels of ground water confined in the basalt stands higher than the level of the main water table in the Columbia River valley. Thus, the relative altitude of the water table beneath the reservoir area depends upon the degree of structural control and the quantity of ground water available for transfer over or through the structural barriers. The information preserved by Waring (1913) and the subsequent meager data on water wells indicate that, for the northern and central parts of the reservoir area, the potentiometric surface of the ground water in the top and second basalt flows slopes from a few tens of feet below the surface at the 500-foot surface contour southward to the land surface at the 350-foot contour. Also, the data indicate that the ground water in the lava flows that occur at progressively greater depths below the second basalt flow is confined under progressively greater pressures and that the resultant water levels in wells, drilled to these deeper zones, will stand higher than 350 feet in altitude.

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