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BASALT STRATIGRAPHY - PASCO BASIN

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PASCO BASIN

The Yakima Basalt, a subgroup of the Columbia River Basalt, underlies most of the 200,000-square-kilometer Columbia Plateau of southeastern Washington, northeastern Oregon, and the western margin of central Idaho. The 5,500-square-kilometer Pasco Basin is 1 of 4 large structural and topographic basins clustered near, but skewed southwest of, the center of the plateau. These alluviated basins are partly surrounded by numerous anticlinal ridges formed by deformation in Miocene and Pliocene time of the basalt flows that occupy the western half of the plateau. The basins, anticlines, and synclines are superposed upon a broad downwarp that encompasses the entire plateau. This downwarp started while the Columbia River Basalts were being extruded, and continued until at the least late Pliocene-Pleistocene time. The Pasco Basin is the structural basin that lies closest to the center of this downwarp and probably is the one that received the thickest fill of basalt flows.

Boreholes establish that the accumulation of Yakima Basalt flows beneath the central Pasco Basin totals more than 1,500 meters. From 0 to 200 meters of glaciofluvial flood deposits and older fluvial to lacustrine sediments are penetrated by the boreholes before they reach basalt, and several thin "interbeds" of fluvial and volcaniclastic sedimentary rock occur between many of the basalt flows in the upper 300 meters of the basalt section. These sediments and all but the deepest basalt flows cored from the drill holes can be examined in surface outcrops in and around the margin of the Pasco Basin. The best of the surface exposures of basalt are in the precipitous-walled water gaps that antecedent Columbia and Yakima Rivers sawed through the anticlinal ridges as they rose.

It became necessary to determine the detailed stratigraphy and structure of the basalt beneath the Pasco Basin. Many organizations and hundreds of individuals are, or have been, involved in this work. It is still an on-going project.

STRATIGRAPHY

It has been possible to characterize and describe a nearly complete flow-by-flow stratigraphic column containing more than 50 flows, and to make valid correlations from borehole to borehole and from cores to outcrops. The methods found most useful in characterizing and discriminating between flows (and larger stratigraphic units) of basalt are the well-established ones of detailed geologic mapping (assisted by petrography and chemistry) and of subsurface geology derived from drill cores and borehole geophysical logs. The data gained from these activities are then interpreted in the framework of studies generally called "Basin Analysis." But, because basalts are different kinds of accumulations than the rocks found in sedimentary basins, the ordinary techniques of Basin Analysis must be modified. Two basic procedures of Basin Analysis, however, are still fundamental:

A. Detailed Geologic Mapping of Surface Exposures
(The Pasco Basin is now completely mapped at scales of 1:24,000 and and 1:62,500.)

B. Drilling and Geophysical Logging
(Twelve deep boreholes [1,000 meters or greater] and 12 of intermediate depth [approximately 300 meters] were drilled. Geophysical logs and analyses of core from these holes furnish the data base used for the Pasco Basin.)

In the course of mapping and drilling, much aid in guiding the progress of the work, and particularly in identifying specific basalt flows and correlating them from borehole to outcrop, has come from a variety of techniques and methods not normally used for sedimentary basins. The more important ones are described below.

MAJOR ELEMENT CHEMISTRY

Chemical analyses of samples by X-ray fluorescence have been the most useful single tool to check tracing of flows in the field, or to correlate them between boreholes. Some flows have a virtually unique chemistry. Many groups composed of 2 to 5 flows can be separated from similar appearing groups by significant changes in MgO, TiO_2, or various ratios of other oxides. These changes are readily detected using variation diagrams and--for boreholes--strip plots of oxide concentration versus drilled depth. We can also make similar discriminations from trace elements.

With sufficient number of superior chemical analyses of specimens from the cores and from measured field sections, a "chemical stratigraphic column" can be set up for the cores and matched with the lithologic stratigraphic units used in field mapping. This serves to cross-check and refine each column.

PALEOMAGNETIC INVESTIGATIONS

Paleomagnetic polarity was determined in the field with a fluxgate magnetometer while the field maps were being prepared. Paleomagnetic polarity and variations in inclination can be obtained from core, even if the core is unoriented by azimuth (but it must be right-side-up in the core box). Magnetostratigraphic correlations can be made using polarity changes and inclination variations. This magnetostratigraphy can be superposed on the lithologic and chemical stratigraphic correlations to further confirm and refine the stratigraphic framework.

BOREHOLE GEOPHYSICAL LOGGING

After some experimentation and testing, it was found that geophysical logging of boreholes in basalt is an extremely useful method of establishing stratigraphic relationships and correlating individual basalt flows over the Pasco Basin. The results are especially rewarding when combined with results from core logging, chemical and petrographic studies of the cores, paleomagnetic analyses, and other physical and chemical tests. Initially, most of the standard logs routinely used in drilling for oil in sedimentary basins were tried. Many were ineffective, but the sonic, density, porosity (neutron log), and gamma-ray logs have proved to be particularly useful in basaltic terrains. The first three of these logs are effective in locating the contact between flows, and also in showing intraflow variations. Figure 1 shows how 5 kinds of geophysical logs compare with lithology of the core (right side) and with a plot of the "chemical types" of the flows obtained from chemical analyses of the cores (left side). The sonic log is especially sensitive for locating flow contacts and intraflow variations.

The gamma-ray log measures the natural radioactivity of rock units and in basalt boreholes it is sensitive to the presence of ^{40}K. Thus, it emphasizes the flow with unusually low K_2O, and it also responds to a difference in K_2O content with the high-MgO and low-MgO flows. It also picks up thin clay interbeds or weathered zones that are often not recovered during coring operations. Potassium is concentrated in the clay minerals and muscovite over the amount ordinarily found in fresh basalt flows.

OTHER GEOPHYSICAL SURVEYS

Additional geophysical surveys, not tied directly to borehole logging, were used to determine the depth to basalt hidden beneath a cover of sediments, to trace buried structural features, and to look for the base of the basalt pile. The most rewarding results are from magnetotelluric surveys, reflection-seismic surveys, and aeromagnetic and surface gravity surveys.

GRANDE RONDE BASALT ACCUMULATION IN THE PASCO BASIN

Enough basalt flows have been dated by several different laboratories to show that the maximum period of accumulation of the Columbia River Basalt was about 16 to 14 million years before present. According to Swanson and Wright (1978), 99 percent of the flows, by volume, were erupted during this interval. The bulk of these flows (about 85 percent) is the Grande Ronde Basalt.

As one would expect, the post-Grande Ronde flows are generally separated by interbeds of fluvial sediment, tuff, or saprolite. Such interbeds are sparse among the much more rapidly accumulated Grande Ronde flows cored in the Pasco Basin. These older flows, however, do show interbeds and extensive pillowed zones where they tapered out against the bordering uplands of the Cascades, Okanogan Highlands, and northern Rocky Mountains.

At least two somewhat contradictory implications may be drawn from these data: (A) either the Grande Ronde flows (fed from vents to the east, as generally assumed) reached the center of the basin so quickly and, in such great floods, that the Pasco Basin (assuming it existed during Grande Ronde time) was filled to overflowing most of the time, and only a few of the very largest (and youngest) flows made it to the periphery of the plateau on the west, north, and northeast, or (B) the Grande Ronde floods were fed from elsewhere--perhaps from directly beneath the Pasco Basin. If this were true, the westward-dipping paleoslope that quite definitely did occupy the eastern part of the basalt field during post-Grande Ronde time--Bingham, Swanson, Price, Reidel, and others have found the vent systems for many of these flows and traced them westward into the Pasco Basin--did not exist in Grande Ronde time. The second hypothesis gives a sensible explanation of why the foreset-bedded palagonite tuffs (Fuller, 1931) and the pseudointrusive relation of basalt flows to interbeds are directed radially outward from the Pasco Basin; west and southwest in the Columbia Gorge, west against the ancestral Cascades, northwest and north against the Chelan area and Okanogan Highlands, and north and northeast in the Spokane and Coeur d'Alene parts of the northern Rockies.

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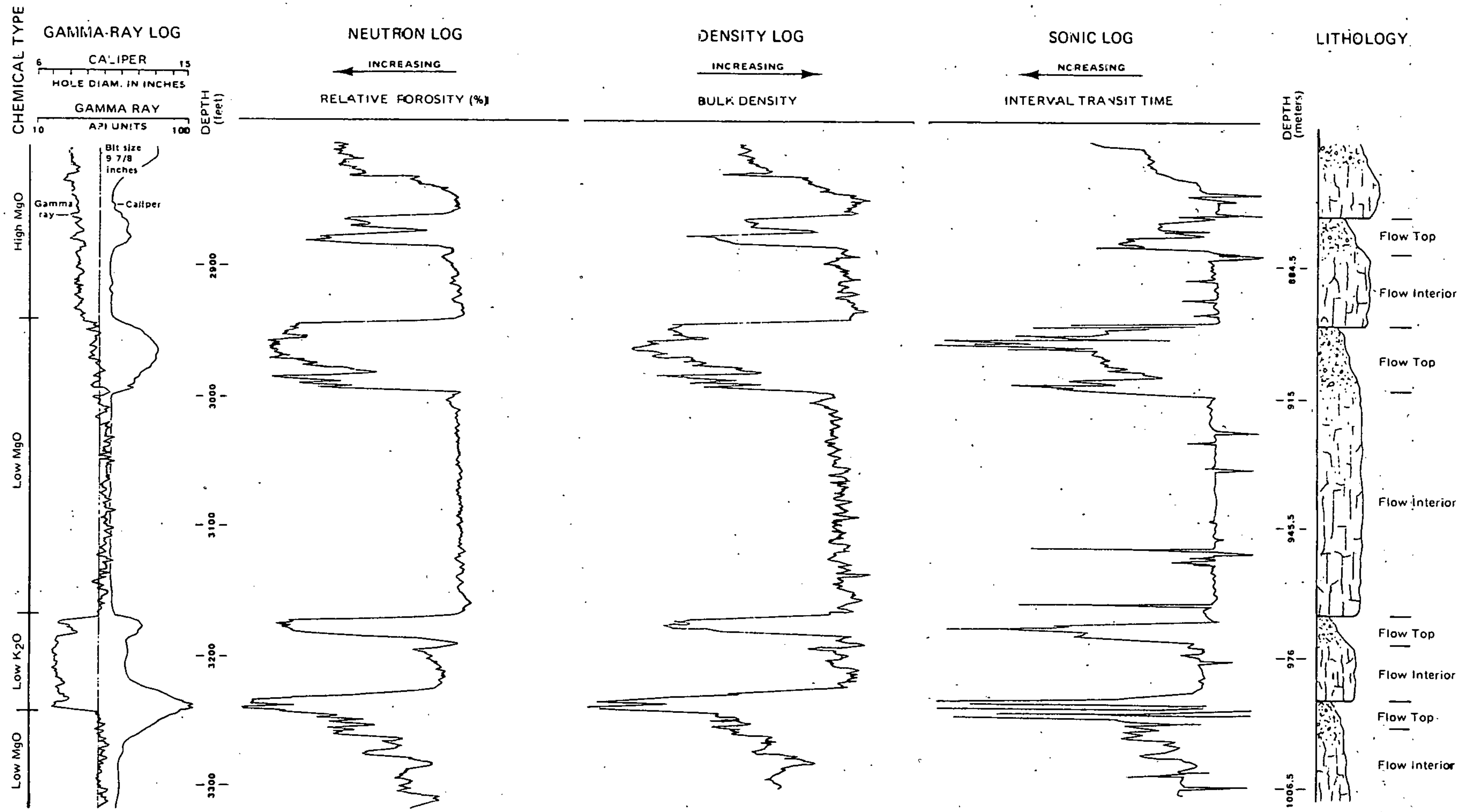

FIGURE 1. Illustrative Wireline Log Response in Columbia River Basalt. Flow tops have higher porosity, lower density, and higher interval transit time than flow interiors. Gamma-ray log is sensitive to chemical types with different potassium percentages.

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