



*Summary of the Structure and Geomorphology of the
Columbia River Basalt*

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THE PURPOSE of this summary of the structure and geomorphology of the Columbia River basalt formation or series of Oregon, Washington, and adjacent parts of Idaho is to review that which is generally accepted and to point out the problems needing investigation. It might be said that any point upon which there is a serious lack of agreement needs further investigation.

The name "Columbia River basalt" as used in this paper refers to the series of basaltic flows, generally assigned a Miocene age, that were described by J. C. Merriam (1901) and to which he restricted the name. In the John Day basin this series lies between the John Day and the Mascall formations. From this point it can be traced directly to the Columbia River valley and for many miles along this major river and its tributaries. The Columbia River basalt is no doubt the most widespread series of basalt in the group of extrusives which I. C. Russell (1893) named the "Columbia lava" and later (1901) changed to the "Columbia River lava."

Other extrusive flow rocks, including large amounts of basalt, of Eocene and Oligocene age and also others of Pliocene, Pleistocene, and perhaps Recent age, are found in the same region as the Columbia River basalt and were presumably included by Russell in his Columbia River lavas although it is doubtful if the great variety of volcanic types was appreciated at that time. Obviously the name Columbia River basalt is not applicable to the wide variety of non-basaltic extrusives and the usage of the name in Oregon, with but few exceptions, has been consistent with Merriam's restriction of the term. Basaltic flows of generally equivalent age in Washington were named the "Yakima basalt" by G. O. Smith (1901).

The Columbia River basalt was extruded upon an erosional surface carved upon rocks of varying ages and with varying degrees of relief. The thickness ranges from that of a few flows surrounding island peaks and embayments along the margin of the lava sheet to more than a mile in thickness closer to the center of extrusion and points of greatest subsidence. Although it is acknowledged that the base may be quite irregular, it is presumed that the initial surface of the series was quite flat and it is upon the attitude and elevation of the exposed flows that the structure of the Columbia River basalt is determined. Vertical dissection of the series is evident but it is doubtful if lateral stripping of large areas has occurred in many places. Although erosion surfaces are recognized, these usually truncate deformed basalt. Even if flows were stripped, the attitude of the remaining flows would indicate the structural pattern.

There appears to be two prominent types of deformation affecting the Columbia River basalts: first, compressional folds and association faults in which crustal shortening has occurred, and, second, vertical adjustment resulting in broad scale warping and some faulting.

COMPRESSIONAL FOLDS AND FAULTS

COMPRESSIONAL FOLDING started in western Oregon and western Washington after the formation of an extensive deposit of high-iron bauxite on top of the Columbia River basalt. This stage of laterization evidently took considerable time for development and during this interval of time the basalt sheet lay near baselevel. C. R. Warren (1941: 226) on wholly independent evidence suggested that there was an interval between extrusion and deformation. This interval may have occupied the upper part of the Miocene epoch. Folding, which followed, in large part preceded the deposition of the Troutdale and Dalles formations. These formations have been assigned to the lower Pliocene by Chaney (1944). There was some erosion on the crests of the basalt folds prior to the deposition of the overlying Pliocene formations. In eastern Washington folding reached a greater intensity and apparently persisted longer, because beds of the Ellensburg formation, along with the basalt, are in places steeply folded, also post-Ringold deformation was noted by Culver (1937) in the Horse Heaven Hills and in the Saddle Mountains. C. R. Warren (1941: 226) suggested that folding and uplift of the Horse Heaven Hills caused deposition of the Ringold formation and thus the deformation would be of Ringold age, presumably Upper Pliocene or Lower Pleistocene. However, if

the Dalles and Troutdale formations of Lower Pliocene age are largely post-folding in the Cascade Mountain area, there seems to be no reason to suppose that deformation is significantly later a short distance to the east and the evidence does not seem to bear out this narrow time of deformation. There are perhaps other plausible causes for the deposition of the Ringold formation besides uplift of the Horse Heaven Hills.

It is apparent that in a discussion of the age of folding of the region we are of necessity bound to the age assignments given the various stratigraphic units. Since many of the age assignments are tentative, more work is necessary in order to date more correctly these stratigraphic units.

Faulting of the basalt occurs in the Saddle Mountain, Rattlesnake Hills, and Horse Heaven Hills according to Culver (1936: 31). Some of these faults parallel the trend of the hills and are evidently the result of the same stage of compression.

The trends of the folds are north to northwestward in northwestern Oregon and adjacent parts of Washington. Hodge (1938) has shown that the basalt in the Cascade Range exposed in the Columbia River Gorge is made up of several rather well defined anticlines and synclines which trend southwestward toward the edge of the Willamette Valley. Hodge (1942) has mapped the structural trends of the basalt in northcentral Oregon. Many of these parallel the southwestward trend in the Cascade Mountains; others are eastward. In central Washington several well defined anticlinal folds, such as those along the Yakima River, in general show a westward and in some instances a northwestward trend. The structure of some of these has been described by Smith (1901, 1903). Structural trends of the folds mentioned, and many others, have been plotted on the Tectonic Map of the United States, published by the American Association of Petroleum Geologists, 1944.

VERTICAL ADJUSTMENTS

SUPERIMPOSED UPON the folded Columbia River basalt is a pattern of regional warping. In this case, as opposed to the folded basalt, adjustments have been caused by dominantly vertical stresses, perhaps often the result of isostatic adjustment. Much of the warping is younger than the stage of compressional folding. Prominent downwarps and arched areas include the Willamette Valley and its continuation northward into Washington; the Cascade Range, which, as noted, has well defined folds upon which the regional arching has been superimposed; and east of the Cascade Range the downwarped Pasco or

Columbia River Basin is perhaps one of the dominant structural features. To the south there is the Ochoco-Blue Mountain uplift. This warping has tilted the earlier compressional folds.

The Horse Heaven Hills plunge eastward from the Cascade Range and westward from the Blue Mountain uplift with the low part at the Wallula Gap. The elevation at the Cascade margin of the basalt is nearly 7000 ft. Many ridges, such as Athaneum Ridge, plunge eastward. W. C. Warren (1941: 812) mentioned this tilting toward the center of the Columbia River Basin and pointed out as well the regional dip of the basalt from the north and from the area along the Washington-Idaho boundary toward the center of the basin. The Wallowa Mountains were likewise uplifted and many of the border faults probably occurred during uplift. Faulting as occurred along the Columbia River (Hodge, 1931) also probably resulted from vertical adjustments.

The dating of the movements is of vital importance to an understanding of the post-basalt stratigraphic history and the study of the geomorphology of the region. As pointed out, compression evidently began in the uppermost Miocene or early Pliocene with perhaps some intermittent movement in the Pliocene. Warping is for the most part later and is conceded by many writers to be Pleistocene. In discussing the Central Mountains, Freeman, Forrester, and Luper (1945: 66) state, "the final episode of deformation apparently was delayed until the early Pleistocene. It was largely one of regional uplift and local warping and faulting that marked out most of the present basins, plateaus, and ranges of the Central Mountains and elevated the highest portions to altitudes of 9000 and 10,000 feet above sea." The time of uplift probably corresponded in many other parts of the region underlain by the Columbia River basalt. However, there is a possibility that movement continued into the Recent.

At the Dalles, Piper (1932) noted several faults which offset the basalt. Although most of the recent movement has been an upward rebound on the down-thrown side of the faults, the net effect is still an uplift of the eastern side. Thus if faulting is relatively recent, as indicated by Piper, the dominant uplift of the eastern side may have caused the falls and rapids in this region.

GEOMORPHOLOGY

ONLY A BRIEF DISCUSSION of the geomorphology of the region underlain by the Columbia River basalt will be attempted. The basalt is the most

resistant formation in the area and forms the dominant topographic features of the region. These topographic features have been grouped in physiographic units by Freeman, Forrester, and Lupper (1945).

At present many of the streams flow through relatively deep canyons along the margins of the broad basins before emerging onto the basin floor. Others flow through a series of water gaps such as those along the Yakima River and at Wallula Gap. Intervening valleys have been partially or entirely filled by Pliocene or Pleistocene sediments so that in some cases the river has been superimposed upon the basalt in its present course. The shifting of the Columbia River from its antecedent course at Status Pass in the Horse Heaven Hills to the present Wallula Gap, as proposed by C. R. Warren (1941), may have been accomplished by the river shifting on a regional fill. In other cases superimposition from a sedimentary fill is not the answer and it is probable that some of the streams are antecedent to the rise of the ridge or mountain. The arching of the Dalles-Troutdale sediments in the Cascade Range indicates that the present course of the Columbia River is antecedent to the uplift of the Cascade Range. The river may have been flowing on a sedimentary fill in a broad valley and let down upon such volcanic feeders as Wind and Shellrock Mountains, but the course still appears to have been antecedent to the uplift of the range. There may be other cases where the problem of antecedency or superimposition have not been solved.

If diastrophic movement is relatively recent, as appears to be the case at the Dalles, many rapids and ungraded portions of the major streams may be due to recent uplift or faulting. The youthfulness of such canyons as Hells Canyon points to rapid uplift, which may be continuing. One of the important problems is that of integrating deformational movements with the geologic history of the region. Could warping have continued recently enough to have tilted some of our glacial and interglacial deposits? Is some of this caused by rebound from the weight of the ice sheet? Have the scabland channels been steepened by uplift of the northern border and depression of the basin near Pasco since their formation? Could the elevations of some of the prominent erratic boulders along the Columbia River below the icesheet be explained in part by uplift during regional deformation rather than by levels of lakes behind ice jams?

Work by the writer along the coast of Oregon (1945) and previously along the coast of Washington showed that the lowest prominent terrace had been warped so that elevations varied as much as 250 ft. If this terrace is dated

correctly, it is younger than early Wisconsin. Near the sea, where a level plane for comparison exists, it is not difficult to note the deformation. However, one wonders if much of the Columbia Intermontane province may not have been warped as much or even more since the early Wisconsin. A closer examination of the facts might disclose the part of relatively recent deformation in our geological history.

These are but a few of the questions that might be asked concerning the deformational and geomorphological history of the Columbia River basalt and the formations underlain by it.

LITERATURE CITED

- Baldwin, E. M. 1945. Some revisions of the Late Cenozoic stratigraphy of the southern Oregon Coast. *Jour. Geol.*, 53:35-46.
- Chaney, R. W. 1944. Pliocene floras of California and Oregon. Chap. 12, The Troutdale flora. Carnegie Inst. Wash. Pub. 553:323-352.
- Culver, H. E. 1936. The geology of Washington. Pt. 1, General features of Washington geology (to accompany geologic map), Wash. Dept. Cons. and Devel., Div. Geol. Bull. 32, 70 pp.
- . 1937. Extensions of the Ringold formation. *Northwest Sci.*, 11 (3):57-60.
- Freeman, O. W., J. D. Forrester, and R. L. Lupper. 1945. Physiographic divisions of the Columbia Intermontane province. *Assoc. Amer. Geographers Annals*, 35 (2):53-75.
- Hodge, E. T. 1938. Geology of the lower Columbia River. *Geol. Soc. Amer. Bull.* 49 (6):831-930.
- . 1931. Columbia River fault. *Geol. Soc. Amer. Bull.* 42 (4):923-984.
- . 1942. Geology of north central Oregon. *Oregon State Coll. Studies in Geol.* (3) 76 pp.
- Merriam, J. C. 1901. A contribution to the geology of the John Day Basin. *Univ. Cal. Dept. of Geol. Sci. Bull.* 2 (9):269-314.
- Piper, A. M. 1932. Geology and ground water resources of the Dalles region, Oregon. U. S. Geol. Surv. Water Supply Paper, 659-B:107-189.
- Russell, I. C. 1893. A geological reconnaissance in central Washington. U. S. Geol. Surv. Bull. 108:21-24.
- . 1901. Geology and water resources of Nez Perce Co., Idaho. U. S. Geol. Surv., Water Supply Paper 53.
- Smith, G. O. 1901. Geology and water resources of a portion of Yakima Co., Wash. U. S. Geol. Surv., Water Supply Paper 55.
- . 1903. Description of the Ellensburg Quadrangle (Wash.). U. S. Geol. Surv., Geologic Atlas 86.
- Warren, C. R. 1941. Course of Columbia River in southern central Washington. *Amer. Jour. Sci.*, 5th Ser., 239 (3):209-232.
- Warren, W. C. 1941. Relation of the Yakima basalt to the Keechelus andesitic series (Wash.). *Jour. Geol.* 49:795-814.