THE SPOKANE FLOOD: A DISCUSSION[1]

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During the summers of 1921 and 1922 the writer, in connection with the routine task of topographic mapping in the Corfu, Scooteney Lake, and Hanford quadrangles, Washington, was able to observe in a reconnaissance way a number of the unusual features that have since been so ably described by Professor Bretz.[2] Although the whole region possesses a fascination that tempts a discussion of many of the problems presented, the writer wishes to confine his attention to one particular phase with which he is most familiar, namely, those records of the glacial history that have been left upon the surface of the Ringold formation in the area south of the Saddle Mountains. An interpretation of these records differing radically from that given by Bretz[3] is believed to fit the field facts more satisfactorily than does his hypothesis, and it has a further advantage in that no catastrophic element is involved in its development.

The Columbia River, after cutting from north to south through the Saddle Mountain uplift below Beverly, swings first eastward, then northeastward, to Wahluke, below which town it swings back sharply again to the general southeasterly course that it follows as far as the junction with the Snake. The Ringold formation, lacustral in origin[4] and of preglacial Pleistocene (?) age, appears as the only

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[2] J Harlen Bretz, "Glacial Drainage of the Columbia Plateau," *Bull. Geol. Soc. Amer.*, Vol. XXXIV (1923), p. 573; "The Channeled Scablands of the Columbia Plateau," *Jour. Geol.*, Vol. XXXI (1923), p. 617; "The Dalles Type of River Channel," *Jour. Geol.*, Vol. XXXII (1924), p. 139; "The Age of the Spokane Glaciation," *Amer. Jour. Science*, Vol. VIII (1924), p. 336; "The Spokane Flood beyond the Channeled Scablands," *Jour. Geol.*, Vol. XXXIII (1925), pp. 97–115, 236–59.

[3] *Op. cit.*, *Jour. Geol.*, Vol. XXXIII (1923), p. 646; *op. cit.*, *Jour. Geol.*, Vol. XXXIII (1925), p. 115.

[4] George Otis Smith, "Geology and Physiography of Central Washington," *U.S. Geol. Survey Prof. Paper 19* (1903), p. 18; Frank C. Calkins, "Geology and Water Resources of a Portion of East-Central Washington," *U.S. Geol. Survey Water-Supply*

formation on the north and east sides of the river over most of this course.[1] Between the Saddle Mountain water gap and Wahluke it is expressed topographically in the form of a subdued high-level terrace whose summit rim lies at a variable distance back from the river,[2] but below Wahluke the river has so crowded against its east bank as to produce a precipitous, and in many ways spectacular, bluff in the Ringold formation known as the White Bluffs of the Columbia, in allusion to the light gray, white, and cream color of the mudstones and silts that make up the greater part of the formation. The rim of the White Bluffs stands from 300 to 600 feet above the Columbia River between Wahluke and Ringold, the lower levels at the north being correlated with the nearness of the Saddle Mountains and the resultant concentration of the run-off. As will be brought out later, most of this erosion at the north was accomplished under former climatic conditions of less aridity than those prevailing at the present time.

The surface of the Ringold formation above and for several miles to the east of the White Bluffs is essentially a level plain of aggradation.[3] That this plain formerly extended westward 15–20 miles to the Yakima and Rattlesnake ranges is evident from the inadequacy of any alternative possibility even if there were no collateral lines of evidence; the Ringold beds have been undisturbed in the region south of the Saddle Mountains,[4] and the Yakima and Rattlesnake ranges are the only possible limits of the basin in which the lake beds could have accumulated to the present exposed thickness in the White Bluffs. Confirmatory evidence of this westward extension was

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Paper 118 (1905), p. 36. Merriam and Buwalda, however, on the evidence of mammalian remains found at two localities between Hanford and Ringold, conclude that at least part of the series is of flood-plain origin.

[1] John C. Merriam and John P. Buwalda, "The Age of Strata Referred to the Ellensburg Formation in the White Bluffs of the Columbia River," *University of California Publications in Geol.*, Vol. X (1917), p. 255.

[2] All the features here discussed are shown on the Scooteney Lake, Hanford, and Coyote Rapids quadrangles.

[3] Merriam and Buwalda, *op. cit.*, p. 262.

[4] The component of dip measured parallel to the bluff by the writer accounted for a difference in the elevation of a given horizon of only 8 feet in 5 miles, and it is believed that the amount would be of the same order of magnitude if taken in any other direction.

found by Merriam and Buwalda, who state that isolated patches of the Ringold formation appear at various points on the west side of the river.[1]

These Pleistocene (?) lake beds have been removed from the region west of the Columbia by a process of lateral planation by the river.[2] Normal erosion by rainwater is ruled out when the almost complete lack of any dissection by local drainage of the Ringold plain east of the White Bluffs is considered. Further and conclusive proof that the Columbia has shifted over this region is shown by the presence over extensive areas west of the river of coarse stream gravels and cobbles that are similar in size, shape, and lithologic composition to those of the present-day Columbia Channel. Many of these deposits appear as huge river bars inclosing undrained depressions.

The surface of the Ringold plain east of the Columbia is cut by three dry coulees that head at the east end of the Saddle Mountain uplift, in the scabland plexus termed the "Othello channels" by Bretz. After pursuing a southwestward course, these coulees debouch at different elevations as hanging valleys along the White Bluffs. All are markedly U-shaped in cross-section. The master-channel of the three is Koontz coulee, which debouches at Ringold at an elevation of 150 feet above the river. In its lower and better defined portion it is $1\frac{1}{2}$ miles wide and its bed lies from 300 to 350 feet below the flat, undissected Ringold plain which borders it abruptly on the northwest. A subsidiary channel of smaller dimensions (three-quarters of a mile wide, 100 feet deep), which is here treated for convenience as a part of Koontz coulee, leaves the latter about 10 miles back from its mouth, and after following a subparallel course 2 miles southeast of the main channel, enters it again at the point where it joins the Columbia. At its mouth this "parasitic" coulee hangs about 125 feet above the floor of Koontz coulee, but at its source it merges with the main channel in such a way that the cross-sectional profile, instead of presenting a marked topographic break at the junction of the two channels, shows an even ascent from the deepest part, along the foot of the northwest wall of Koontz coulee, to the east wall of the smaller channel.

[1] Merriam and Buwalda, *op. cit.*, p. 262. [2] *Ibid.*

Headward, Koontz coulee opens out, funnel-like, onto a scabland floor, and finally loses its identity in an intricate maze of interlacing scabland coulees, the Othello channels of Bretz. These channels cross the divide at the east end of the Saddle Mountains over a front of several miles. Huge rock-bound depressions are characteristic land forms throughout this tract, the most striking example being the one that holds Scooteney Lake. Neglecting the linear tract about 5 miles long that is inclosed within the top depression contour northwest of the lake, the rimrock basin proper is a little over 2 miles long, 1,000 feet wide, and 150 feet deep.

The two other remaining dry coulees are of mutually comparable size, averaging less than half a mile in width and from 75 to 150 feet in depth, and are thus much smaller than Koontz coulee. They head at essentially the same point in the west rim of Koontz coulee 12 miles above its mouth, at an elevation of 250 feet above its bed, and, after following divergent courses, reach the bluff of the Columbia at points 2 and 15 miles, respectively, above the mouth of Koontz coulee and at elevations of 425 and 300 feet, respectively, above the Columbia. Both in turn show remnants of still shallower braided channels at higher levels, appearing as short shunts off the primary channels. The southern of these dry coulees maintains its U-shape practically up to the point where its profile breaks off abruptly to the level of the Columbia; the inclosing walls of the northern coulee, on the contrary, begin to recede diagonally and to flatten at a point 5 miles back from the river, so that the incised character of the coulee is soon lost, though the old drainage line can still be traced through to the bluff overlooking the town of White Bluffs.

That all three of the dry channels described previously were produced under drainage conditions widely different from those prevailing at the present time is amply proved by the sage-covered depressions in the two smaller coulees, and by the scattered rock depressions in the upper regions of Koontz coulee.

Mr. Bretz has interpreted these dry coulees as the product of huge glacial torrents that emptied into the Columbia when its flood waters stood at or slightly above the levels of the present mouths of the coulees. That these are at different levels is believed by him to be due to the different stages in which they were abandoned during

the lowering of the flood of the Columbia, Koontz coulee being the last one abandoned. The bed of the river at the time of this flood is believed by him to have been at essentially its present level.

The writer believes that the three dry coulees were formed by the glacially diverted Columbia[1] at a time when the normal river channel lay several miles west of its present channel, and that they have since been converted into hanging valleys by the lateral shift of the river to the east against the soft sediments of the White Bluffs. The higher coulees are believed to be distributaries formed early in the history of glacial drainage across the Ringold plain and abandoned after Koontz coulee had gained the mastery.

That this lateral shift is a reality today is proved by the vigorous manner in which the river is undercutting the bluff. Elsewhere in the region the soft Ringold sediments tend to weather into soil-covered slopes with the obliteration of all natural exposures, even under the existing conditions of aridity; in the bluffs, however, so incessant has been the crowding by the river that the slopes have been steepened far beyond the normal profile of equilibrium, and good exposures have been correspondingly favored to the point where they have become the rule rather than the exception. Landslides off the face of the bluff are numerous, and some of them are uncommonly large. One opposite Hanford has left an undrained depression behind it 1½ miles long, 1,000 feet wide, and 100 feet deep.

Projection of the profile of Koontz coulee to meet the topographic slope on the west side of the Columbia indicates that the river lay approximately 3 miles west of its present position when the coulee

[1] The suggestion that the Columbia River was diverted across the Big Bend country by an ice dam west of the head of Grand coulee is not a new one, but has appeared frequently in the previous literature on the region.

See T. W. Symons, "Report of an Examination of the Upper Columbia River," *Forty-Seventh Congress, 1st Session, Sen. Doc. No. 186*, 1882; I. C. Russell, "Geologic Reconnaissance in Central Washington," *U.S. Geol. Survey Bull. 108* (1893), p. 91; W. L. Dawson, "Glacial Phenomena in Okanogan County, Washington," *Amer. Geol.*, Vol. XXII (1898), p. 203; R. D. Salisbury, "Glacial Work in the Western Mountains in 1901," *Jour. Geol.*, Vol. IX (1901), pp. 721–24; F. C. Calkins, "Geology and Water Resources of a Portion of East-Central Washington," *U.S. Geol. Survey Water-Supply Paper 118* (1905), pp. 43, 44; Karl Oestreich, *Die Grand Coulee* (memorial volume of the Transcontinental Excursion of 1912), American Geographical Society, 1915; A. T. Schwennessen and O. E. Meinzer, "Ground Water in Quincy Valley, Washington," *U.S. Geol. Survey Water-Supply Paper 425* (1918), p. 135.

was formed. The restored profile of the next coulee to the north cuts the west slope of the valley in approximately the same latitude as does Koontz coulee, but 3 or 4 miles farther west. It would hardly be sound to assume that this distance measures the amount of shift made by the Columbia during the time that glacial drainage crossed the Othello Channel divide, since the profile of the higher coulee is not a smooth curve and we have no assurance that it represents the grade of equilibrium. Indeed, the fact that the profile steepens downstream is rather suggestive that it was still unstable at the time that it was abandoned. A graphic solution of the river's position at the time that these channels were cut is further handicapped by the existence of widespread deposits of dune sand, showing considerable relief (75–100 feet), that borders the west side of the river in a belt several miles wide, directly in line with these hanging coulees. No great reliance can therefore be placed on the actual quantitative values given, yet they do express the general order of magnitude.

The process of lateral planation called upon to account for the removal of all of the Ringold beds west of the river was not continuous, but had at least one important interruption. Gable Mountain, a steep east-west trending basalt ridge 6 miles in length, rises abruptly from the gravel-covered lowland west of Hanford to a maximum elevation of 1,116 feet, which is about 175 feet above the level of the White Bluff's rim. Since this barrier was not removed by the river, the amount of shift to the east and north that has occurred to date must have taken place in two stages; the first terminated when the south face of Gable Mountain was reached, the second began when the local drainage had cut a low enough gap around the north side of the rock to divert the river, and is unterminated at the present day. Under the climatic conditions existing today, headward erosion of any local gulch in the face of the bluff would be a very indefinite and slow process, but when we consider that the feat was probably accomplished in glacial or preglacial time, in at least one of which we have evidence for believing that the climate was somewhat more humid, this difficulty breaks down. Gable Mountain presents a problem that has to be explained whether the interpretation placed by Bretz upon the physiographic history of the White Bluffs region, or the alternative one presented by the writer, is accepted.

It is believed that Bretz's interpretation of the relation of the hanging coulees to the White Bluffs is inadequate to explain (1) the fact that the two smaller dry coulees previously described, although heading at the same place, reach the White Bluffs above the Columbia at different elevations; (2) the fact that a V-shaped valley along the southern base of the Saddle Mountains, which heads in the Ringold plain and was produced entirely by drainage from the southern slope of the mountains, also forms a hanging valley 275 feet above the Columbia, although in this case, as with the northernmost glacial coulee, the south slope of the valley breaks back several miles from the river, so that the lower course of the old drainage across the resulting flat is almost obliterated. No run-off ever flows through to the Columbia today, and the lower valley has been largely choked by sand dunes. The fact that this valley is so completely out of adjustment with the present Columbia is proof to the writer that it was formed under climatic conditions of greater humidity than those prevailing today, and has been converted into a hanging valley by the invasion of the river from the west, with the contemporaneous removal by lateral planation of several miles of the lower course of the valley as originally formed. To interpret the level at which this normal erosion valley and the northernmost glacial drainage valley lose their definition by the retreat of their contiguous walls as the ephemeral base level of the Spokane flood, as Bretz has done, is incompatible with the long period that must have been required for the normal valley to have been eroded.

Mr. Bretz interprets the coarse stream gravels and cobbles that cover extensive areas west of the river as the débris of the Spokane flood. The writer believes them to be normal channel deposits of the Columbia during its eastward shift over the area in preglacial, glacial, and post-glacial times.

In summary, four distinct and independent lines of evidence, in the writer's opinion, point to the conclusion that lateral planation by the Columbia has been the dominant factor in the physiographic development of the White Bluffs region: (1) the relation of the present area of the Ringold formation to its former extent, (2) the hanging character of the normal valley at the north end of the White Bluffs, (3) the landslide topography of the present White Bluffs, and

(4) the widespread gravel deposits on the west side of the river. If the development of the V-shaped valley along the base of the Saddle Mountains can be correlated with the glacial epoch, then we have definite proof that much of this lateral planation is of post-glacial age. This established, the many anomalous features presented by the U-shaped channels become readily explainable in terms of the known physiographic history of the region. Even though the glacial age of the normal valley at the north is denied, the writer believes that the explanation of these hanging glacial coulees as developed in this paper is still borne out by the weight of the analogy between the U-shaped valleys and the V-shaped valley; the latter certainly owes its hanging character to the removal by lateral planation of its lower course.

We are thus under no necessity for believing that any unprecedented flood has produced these abandoned channels; Koontz coulee and its congeners were cut in the easily eroded silts of the Ringold formation by glacial or glacially diverted drainage of not extraordinary amounts.