THE SPOKANE FLOOD: A REPLY

J HARLEN BRETZ
University of Chicago

I have several criticisms of Mr. McKnight's argument in the preceding paper. The first deals with a field interpretation and the others with factors and combinations which I believe he has overlooked or misinterpreted, and with a serious inconsistency in his conception. I also have some field evidence to contribute.

The "hanging" normal V-shaped valley in the northern part of the Hanford Quadrangle is eroded in a subdued scarp, 100–150 feet high and a quarter of a mile to a mile wide. This scarp is a definite thing for nearly 15 miles along its irregularities from White Bluffs northeastward to the foot of Saddle Mountain. Both above it and below are distinctly flatter tracts. The valley in question is but one of several which have been developed on this steeper slope. They terminate on the lower flat because of decreased gradient. Where an extension of this valley would have to enter the Columbia, the White Bluffs of the Ringold formation are 225 feet high and their summit level is at least 600 feet A.T. The flat at the top of the bluffs rises 150 feet in about five miles back to the mouth of the valley (or foot of the scarp), and 50 feet of this is within less than a quarter of a mile of the brink of the bluffs. The gradient of the lower part of the valley itself is 60–70 feet per mile, the average of the entire valley is 100 feet per mile.

It is therefore impossible that the valley once extended farther west and has since become obliterated across the lower flat. It belongs to a class which is common enough in youthful drainage systems where regional slopes to be crossed possess marked convexities. These valleys begin as gullies on the crest of the convexity and lengthen both ways, though the mouths are not extended across the flatter tracts beyond the foot of the steeper slope. There are many similar valleys in the region, particularly on Frenchman Hills, north of Saddle Mountain. They are clearly much older than the glacial

spillways. Indeed, the locations of Koontz Coulee and its neighbors probably have been determined in part by just such valleys. Such normal valleys indicate only one thing about the level of the preglacial Columbia: it was somewhere below their mouths when they were formed. They are not properly described as "hanging." No lateral planation or master valley deepening has functioned in their production. The Columbia might well have been a hundred miles away. And that they have any bearing on the level of the glacial Columbia is absurd. My critic is in error when he imputes this inference to me.

Mr. McKnight accepts my interpretation of the gravel deposits about Gable Mountain as great bars and associated depressions; channel forms. He ascribes them to the preglacial, glacial, and postglacial work of the Columbia and gives them no further consideration. But they cannot be dismissed from the problem so simply. We are making a detailed study, confessedly in the hope of securing a more nearly correct interpretation. To neglect any relevant details will imperil the success of the inquiry.

The magnitude of these gravel bars and channels is such that the post-glacial Columbia cannot be held responsible for any of them south and southwest of the great rounded bar north of Gable Mountain. The west end of the mountain is a great cleaver pointing up the Columbia Valley, bare rock to the summit except for talus accumulations. Just west of the cleaver is a large depression, as low as the river 4 miles distant, though separated from it by nearly 3 miles of gravel 100 feet higher. The depression extends eastward along both sides of the rocky ridge, constituting two large channels, one of them twice as wide as the present Columbia. The floor of both channels *rises* downstream 50–75 feet in the 6-mile length of the ridge. Traced upstream, away from the cleaver of Gable Mountain, the floor of the depression rises 100 feet in a mile and a half. And the immediately surrounding hills, the gravel bars, stand 150 to 200 feet above the depression. Clearly Gable Mountain was an island when these features were formed, and clearly the water surface was more than 600 feet A.T. when the hole into which the cleaver projects, as deep as present river level, was formed by a great deflection eddy. Only the glacial Columbia can be held responsible for these features. The broad flattish tracts and steeper slopes in the gravel look somewhat

like terraces on first inspection. But they cannot be so interpreted, as Mr. McKnight recognizes.

If, now, we attempt to put the immediately post-glacial Columbia anywhere among these channels and bars, it would logically go in the larger, deeper channel along the south side of the mountain. This location is not far from what the projection of the profiles of Koontz and its "parasitic" coulee require. Then, in later post-glacial time, we must shift the Columbia in some way from this channel to the present course, which is essentially no deeper, and in this shift we must pass Gable Mountain and the two glacial river bars which stand between the old channel and the present. One of these bars is at least 2 miles wide, 5 miles long, and 150 feet above the deep place noted. The other is a mile wide, about 4 miles long, and 100 feet above the deep place. Furthermore, a gravel fill then must be made in the head of the abandoned channel, 3 miles long and 100 feet above the deep place. No lateral shifting down a slip-off slope is permissible for this change; it must be an abrupt transfer. I believe that a study of the Coyote Rapids and Hanford sheets will make it obvious that this has never occurred, and it follows therefore that the post-glacial Columbia has always been at least three miles and a half north of Gable Mountain and as far east of this eminence as the longitude of Hanford. Yet the abandoned glacial river channel south of the mountain is as low as the present river surface to the north. The post-glacial Columbia therefore found its broad valley here essentially as deep as at present.

Another puzzle concerning these huge channel forms deals with their successful abandonment without noteworthy modification during the closing stages of occupation. Abrupt diversion might succeed; indeed, it apparently did in the scabland bars and basins back on the plateau. But neither Mr. McKnight nor I can apply this method here. He would have it done by the very gradual process of lateral shifting and valley deepening; I, by an abrupt decrease in volume. Perhaps neither of us is right. I wish to note, however, that rivers do not leave channel forms in their deposits as they shift by lateral planation down slip-off slopes. Deposition on the inside of curves obliterates these. Only terraces or continuous slopes are left. Since the area about Gable Mountain, bearing the great bars and

channels, cannot be interpreted as a slip-off slope, we must conclude that the Columbia has not been west or south of Gable Mountain in post-glacial time. Furthermore, the isolation of the eminence occurred in glacial or preglacial time.

Deposits in the broad valley west of the hanging mouth of the first coulee north of Koontz yield more data that must not be neglected. There is a gravel bar two miles south of Hanford and a mile and a half west of the Columbia, 500 feet A.T. and nearly 150 feet above the river. Sand dunes do not obscure it. About two-thirds of the pebble material is basalt, and its large cobbles and small bowlders are almost all basalt and are very little worn. This bar is traceable northwestward about 4 miles to Gable Mountain. It lies between the two channels which flank the mountain and was built when the mountain was an island in a stream far larger than the present. The glacial Columbia was deep enough and vigorous enough on both sides of Gable Mountain to maintain these channels and to build the subaqueous bar in the protected lee at least 100 feet higher than the lowest channel floor. And by the same evidence, the post-glacial Columbia has been confined to the east side of the bar.

Let us now consider the relationship of this bar to the hanging coulee which mouths four miles and a half east of the bar. It hangs 425 feet above the Columbia, 800 feet A.T. If we add 2 miles to its lower length, i.e., restore 2 miles of the retreating White Bluffs, we narrow the Columbia Channel between the bluffs and the bar as much as anyone would care to do and still allow this major strand of the glacial stream enough volume to shape the east side of the bar. This will put the eastern margin of the glacial river about half a mile west of the present east bank, and not more than 100 feet higher. Some sand dunes have been allowed for in this place. There the projected profile of the hanging coulee will be 725 feet A.T., 275 feet in the air. Mr. McKnight would perhaps increase this projected gradient somewhat, for he remarks that the existing portion steepens downstream, suggesting that it was still unstable when abandoned. But the 500-foot top of the glacial river bar immediately west had an adequate depth of water over it at the time. Its existence debars any placing of the immediately post-glacial Columbia's eastern margin 6 or 7 miles west of White Bluffs (or a distance of that "general

order of magnitude"), as McKnight attempts to do. This situation severely limits the amount of post-glacial retreat of White Bluffs and the post-glacial deepening of Columbia Valley here, by which Mr. McKnight would explain the hanging coulee, and it suggests that my original interpretation may still have some value.

My critic and I both speak of the glacial Columbia as though the term covered a single episode. We both know better. In one of my papers I have described the bars and channels about Gable Mountain as Spokane in age. An alternative conception is that the Gable Mountain bars and channels are Wisconsin in age and that the lateral shift to produce the hanging mouths occurred during the interval between the Spokane and Wisconsin epochs. This would escape the difficulty encountered in the space relations of bar and hanging mouth above noted. But the field data by which the alternative would be supported have not yet been collected. Nor could I prove at present that the Gable Mountain features are clearly all pre-Wisconsin. Though one is tempted to speculate, only more field study can safely indicate what the final interpretation will be.

I wish to call attention to a feature of the White Bluffs which seems significant in this discussion. It is a stretch directly east of the two towns of White Bluffs, where the Columbia swings away from the cliff for about 2 miles. Immediately upstream and downstream the river is now undercutting, and the profile of the bluffs, neglecting landslides, is hardly less than 45° anywhere. The average is nearer 60°.[1] But in the stretch referred to, the slopes are about 25°. They are comparable to the average slopes of the Koontz Coulee bluffs, which are in the same formation (Ringold) and which have had no river at their base since the glacial streams ceased to flow. Several miles of the Koontz bluffs are considerably steeper. I am inclined to think that the post-glacial Columbia has never undercut this stretch. The gentle slope is difficult to explain by Mr. McKnight's conception.

The criticisms thus far set forth are summarized in the following paragraphs.

1. The mouthing of the normal V-shaped valley is determined by the foot of the original steep slope in which it is eroded. Its existence, therefore, has no significance in the problem.

[1] Data taken from the Hanford sheet. I have no field measurements for them.

2. The channels and bars about Gable Mountain are far too large to be ascribed to the work of the Columbia in post-glacial time.

3. If the Columbia had been left in any of these channels on subsidence of the glacial flood, it never could have shifted laterally to its present location without destroying large bars, 100–150 feet above the channel floor.

4. Rivers do not leave channel-bottom débris forms behind them as they widen and deepen their valleys under the conditions imposed by Mr. McKnight.

5. The location of one large bar is so close to the Columbia and to White Bluffs that not more than 2 miles of retreat by post-glacial undercutting can possibly have occurred.

6. The profile of the hanging coulee, directly across the river from this bar, when projected 2 miles into Columbia Valley, is 275 feet above the topographic slope where there must have been a glacial river channel.

7. A portion of White Bluffs where the Columbia now swings away from the cliff has slopes no steeper than those which bound Koontz Coulee. Since it is eroded in the same formation by the undercutting of a large river, it should be of approximately the same age, i.e., glacial.

My final criticism deals with a grave inconsistency in Mr. McKnight's proposed explanation. He would have the surface of the glacial Columbia near the *débouchure* of Koontz Coulee 450–500 feet A.T., or 100–150 feet higher than the present river level. He would have this determined by altitude of its floor. It follows, therefore, that the gradient of the surface of the glacial Columbia was determined by its floor.

Let us investigate this item of gradients. The Columbia today descends 125 feet from the mouth of Wenatchee River to the head of Priest Rapids, a distance of 63 miles; it descends 68 feet in the 10-mile length of these rapids; and it descends 57 feet from the foot of the rapids to the mouth of Koontz Coulee, a distance by river of 42 miles. The ledges which cause Priest Rapids, and several lesser rapids in this 115 miles, have been discovered during the assumed post-glacial deepening. Were there no rapids, the present gradient would be less than 2 feet to the mile.

What was the gradient of the glacial Columbia's surface for 100

miles or so above Koontz Coulee *débouchure?* Could it logically have been much steeper than the present? There were no glacial river rapids over rock ledges in this stretch, for the ledges now being attacked have been incised very little. It seems very improbable that there was a surface gradient of the glacial Columbia, determined by altitude of the channel floor, any steeper than the present.

Now, another glacial river is concerned in the problem: another Columbia. It is the diverted portion that crossed the plateau along the Grand Coulee—Crab Creek route and that split at the eastern end of Saddle Mountain. Part of it crossed this anticlinal feature by way of the canyoned Othello Channels and supplied Koontz Coulee and its neighbors. Part flowed west along the north flank of Saddle Mountain to enter the main Columbia Valley at Beverly. The floor of this latter route does not hang above the Columbia at its *débouchure*, largely because it is a synclinal tract. Its ascent for the first 26 miles east of Beverly is 100 feet. But in the next 6 miles eastward, the floor rises 200 feet. We need trace it no farther, for here was the place of distributary discharge southward to Othello Channels. And the lowest altitude in the head of the diverging spillway is 900 feet, 100 feet above the immediately adjacent Crab Creek Valley, where there then were west-flowing rapids, descending 200 feet in 6 miles.

Can we raise the surface of this diverted Columbia in lower Crab Creek Valley any more above the rock bottom than is allowed at the mouth of Koontz Coulee? McKnight's assumption is that rock floor determines surface of the stream, except for depth of water, and he rules out any extraordinary depth. And the rock floor here has suffered no post-glacial erosion such as is assumed at the mouth of Koontz. The surface of the diverted Columbia, therefore, at this significant place was but little above 800 feet A.T. To discharge toward Othello Channels a sufficient quantity of water to erode the glacial river bed across the divide here and to supply the Koontz Coulee group of spillways the water surface in lower Crab Creek Valley must have been at least 1,000 feet A.T. at this place. This would make it at least 200 feet deep where descending about 30 feet to the mile. And to reach the highest levels scoured by glacial waters here and in Othello Channels, the water surface must have been about 1,150 feet A.T., and the stream 350 feet deep in the

rapids.[1] This is simply impossible by the assumptions on which Mr. McKnight has built. His glacial Columbia never would have discharged through Othello Channels, and he would have had no hanging spillways to explain. Since the discharge did occur, rock floor did not control surface gradients, except in a very general way.

The reader who has followed the argument thus far is now thinking of alternatives and is asking (1) Was not the west-draining lower Crab Creek Valley closed at that time by glacial ice, ice jams, or uneroded Ringold or Ellenburg or Columbia River basalt? (2) Has it not been downwarped subsequent to the Koontz Coulee discharge? (3) Has not Saddle Mountain been upwarped, carrying the Othello Channels relatively higher than when they functioned? (4) Did not Wisconsin discharge, subsequent to the Spokane episode, deepen Lower Crab Creek Valley enough to produce this discrepancy?

My present answer to each of these is "No." Query 4 suggests the most nearly workable alternative. But I believe that there is satisfactory field evidence for each negative, though I hope I am still open to conviction. Since these points were not raised in the preceding paper, detailed discussion is hardly justified here.

I think I am as eager as anyone to find an explanation for the channeled scabland of the Columbia Plateau which will fit all the facts and will satisfy geologists. I have put forth the flood hypothesis only after much hesitation and only when accumulating data seemed to offer no alternative. I would like to see someone not committed to any particular preconception make a field study of that feature of the scablands which Othello Channels typifies; the crossing of divides by the glacial rivers. If the upper scabland levels of Othello Channels, Drumheller Channels, Devils Canyon, Palouse Canyon, and Wallula Gateway can be satisfactorily explained without the ponding at which Mr. McKnight demurs, a long step will be taken toward a more generally acceptable interpretation of the scabland phenomena. Mr. McKnight's analysis neglects this problem entirely.

[1] These measurements are made from this highest part of the diverted Columbia's river bed, which is 5 miles wide. Subsequent erosion has cut a much narrower channel or canyon about 100 feet deeper. Whether this was done later in the Spokane episode or in post-Spokane time does not matter here. When Othello Channels and Koontz Coulee functioned, the water in lower Crab Creek Valley was 1,150 feet A.T.