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THE SPOKANE FLOOD BEYOND THE CHANNELED SCABLANDS

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ABSTRACT

The channeled scablands of the Columbia Plateau in Washington are extensive elongate denuded tracts of basalt, deeply scored by huge high-gradient glacier-born rivers. As physiographic features they are unique. All the rivers which produced them converged to Snake and Columbia valleys, and the record of the tremendous flood thus engendered has been found all the way from the plateau scablands to Portland. Columbia River Valley below the confluence of Snake River carried a flood which at Wallula Gateway was 2 miles wide and reached 750 feet above present river level, at Arlington was 7 miles wide and 450 feet above present river level, at Lyle was 3 miles wide and 430 feet above present river level, and at Portland was nearly 20 miles wide and 350 feet above present river level.

The field evidence for the flood consists of (1) noteworthy, even spectacular, denudation and erosion of slopes below the upper surface of the flood, (2) spreading of the river in favorable places back among preglacial hills, (3) deposition of great gravel bars, some of them nearly as thick as the flood was deep, (4) damming of Snake River above the entrance of the glacial rivers by a delta built upstream against the course of the Snake, and (5) deposition of the Portland Delta, 350 feet thick, 200 square miles in area, and with bars 100 feet high on its surface.

THE PHYSIOGRAPHIC SETTING FOR THE FLOOD

Channeled scabland is limited to that part of the Columbia Plateau which lies between, and above the confluence of, the Snake and Columbia River canyons (Fig. 1). The slope of the plateau in general is southwestward, away from Columbia River on the north and toward Snake River and the lower part of the bounding Columbia

on the south and southwest. Almost all the drainage of the plateau is consequent on this slope.

The Spokane ice sheet crossed the Columbia Valley north of the plateau and advanced a few miles out on it along almost the entire northern margin. Water from the melting of this ice flowed in the preglacial consequent drainage system, entering at or near the heads of these valleys and traversing their entire lengths. The ablation of the Spokane ice sheet must have been extraordinarily rapid, for the volume of water was very great, almost incredibly great, and in spite of high gradients to draw it off, the pre-existing valleys first entered were inadequate to carry it all, and the flood spread widely in a complicated group of anastomosing routes. This pattern is unique in that all the routes were greatly eroded, many of them being developed into canyons of notable proportions by the glacial streams, and some of them crossing prominent preglacial divides on the plateau.[1]

The pre-Spokane drainage of the plateau which entered the Snake was conveyed to one main route, that of Esquatzel Coulee, near Pasco. During the Spokane epoch, two other discharge ways were formed, one through Devils Canyon, near Kahlotus, and one through Palouse Canyon, between Hooper and Perry. The Palouse Canyon route now carries most of Snake River's share of the plateau run-off, Devils Canyon carries none, and Esquatzel Coulee carries but a small portion. This change from preglacial conditions was due to the profound erosion by glacial waters in Palouse Canyon. Greater volume and higher gradient at this place determined the change.

Columbia River had two considerable pre-Spokane tributaries from the plateau, Moses Coulee and Crab Creek. These proved inadequate to carry the Spokane flood, and six others were opened: "The Potholes," Frenchman Springs, and the Koontz Coulee group of channels, the first two being simply cataracts over the cliffs of Columbia Valley. All of these discharge ways leave the west side of that part of the plateau concerned in this study. None of them now carry plateau drainage.

[1] Set forth in some detail in the writer's paper on "The Channeled Scablands of the Columbia Plateau," *Jour. Geol.*, Vol. XXXI (1923), pp. 617–49.

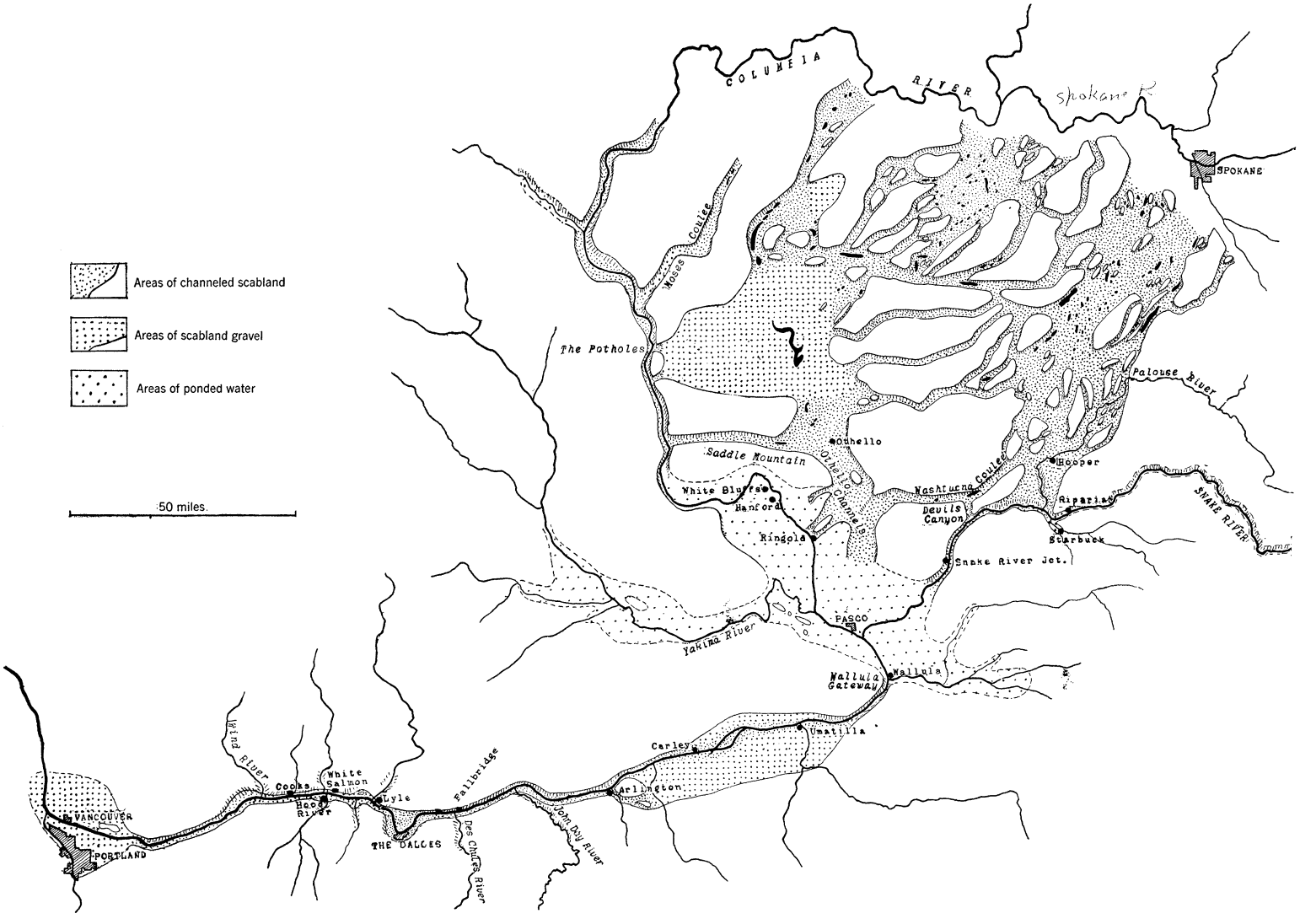

FIG. 1.—Sketch map of the region affected by the Spokane flood

The history of the channeled scablands, very briefly outlined above, has been accepted only with considerable reservation and qualification by many, for the volume of the flood described and the results it produced surpass anything previously known in river phenomena. That this huge volume was a verity, the character of Snake and Columbia valleys below the entrance of the Spokane rivers amply proves. This paper describes the remarkable features produced in these valleys by the concentration of discharge from the scabland rivers. Though details generally render a paper less readable, they are presented here to show more clearly the nature of the field evidence.

THE CHANNELED SCABLANDS

The phenomena which characterize the channeled scabland of the Columbia Plateau are briefly summarized here. The argument thus may be clear without a reading, or re-reading, of the writer's previous papers on the subject.[1]

1. Channeled scabland (Fig. 2) is the eroded surface of the Columbia basalt formation. It is bare rock or is but thinly covered with basaltic débris. It is distributed in an intricate interlacing pattern whose strands are traceable up-gradient to, but not across, the area glaciated by the Spokane ice sheet, and down-gradient to, but not across, the Snake and Columbia valleys. This bare, or nearly bare, rock has a total area of about 2,000 square miles, and its linear tracts are bounded by thousands of miles of cliffs. Basins excavated in the solid basalt are common, many of them at the foot of cliffs transverse to the linear tracts, the sites of former cataracts. Knobs of basalt standing on the floor of the channels are common also.

2. Stream gravel, 99 per cent basalt, occurs in all scabland tracts. Except rarely, it does not occur in terraces, nor does it cover the floors of the channels. It is deposited in great rounded mounds, commonly on the lee side of basalt knobs and elongated with the channels. Less commonly, it lies high up on the sides of the scabland

[1] "Glacial Drainage on the Columbia Plateau," *Bull. Geol. Soc. Am.*, Vol. XXXIV (1923), pp. 573–608; "The Channeled Scablands of the Columbia Plateau," *Jour. Geol.*, Vol. XXXI (1923), pp. 617–49; "The Dalles Type of River Channel," *Jour. Geol.*, Vol. XXXII (1924), pp. 139–49; "The Age of the Spokane Glaciation," *Amer. Jour. Sci.*, Vol. VIII (1924), pp. 336–42.

channels against the cliffs, though here it generally has the rounded, elongated forms. These gravel deposits are interpreted as bars made by the glacial rivers.

3. Above the level of the scablands and their associated gravel deposits is a deep mantle of loess on the plateau. This loess deposit has been dissected to maturity and almost everywhere is in gentle slopes. But along the linear scabland tracts, the loess is steeply scarped, the slopes averaging 30°, all facing and descending to the scabland. There are many isolated hills of loess entirely surrounded

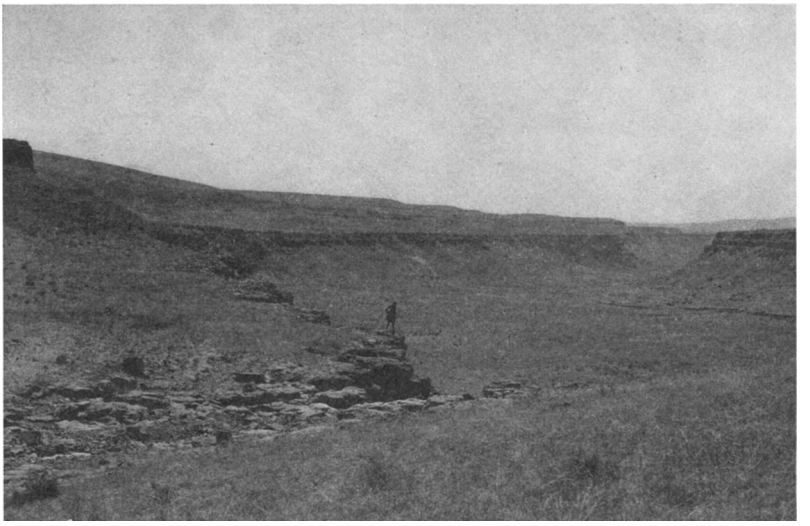

FIG. 2.—Channeled scabland on the Columbia Plateau. The figure in the picture stands on the brink of an abandoned cataract. Photo by F. L. Pickett.

by scabland (Fig. 3), and these commonly have striking prows which point up the scabland gradient. Some of these isolated loess hills, bounded by steep slopes, have the rounded, elongated deposits of gravel on the down-gradient end. The scarps are interpreted as river bluffs of the Spokane glacial streams, produced when the preglacial valleys were not sufficiently deep in basalt to contain the flood which was poured into them. The anastomosing pattern of the whole group of associated phenomena is likewise the consequence of a greater volume than some valleys could carry away, the waters flooding over many minor and some major divides of the plateau.

THE SPOKANE FLOOD IN SNAKE RIVER VALLEY

Between Lewiston and Riparia.—At Lewiston, Idaho, Snake River occupies a structural valley in whose northern wall the Columbia basalt flows are tilted 60° from horizontal. It leaves this open valley a few miles below the Idaho-Washington boundary line and traverses a narrow, winding canyon, cut in nearly horizontal flows of basalt, thence nearly to its junction with Columbia River.

The distance from Lewiston to Riparia is about 100 miles, and the descent is 200 feet. Terraces of river gravel occur on the inside of almost every curve in the course. None of these are more than

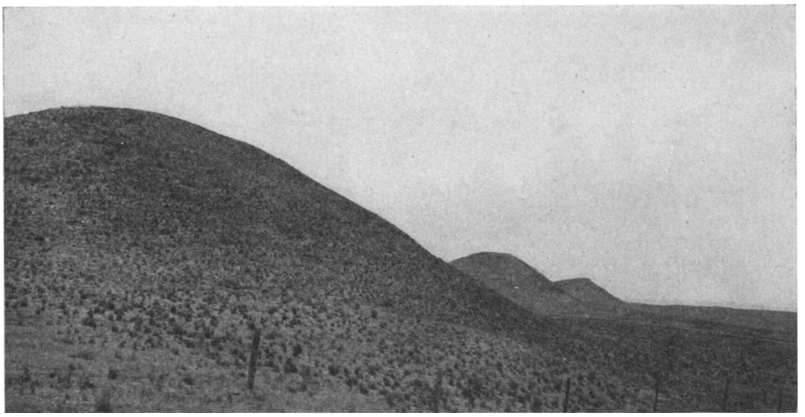

FIG. 3.—Isolated loessial hills on the scabland of the plateau. Photo by F. L. Pickett.

50 feet above the river, if talus and alluvial fan deposits on top of them are not reckoned. Less than 50 per cent of the gravel of which they are composed has been derived from the Columbia basalt. Though the canyon walls are steep, there are no great cliffs, and a mantle of débris and vegetation occurs on most of the slopes. All of these are normal features, and none suggests the occurrence of the Spokane flood in this part of Snake River Valley.

Between Riparia and the mouth of Palouse River.—A great terrace of gravel, 150 to 260 feet above low-water level, lies on the north side of Snake River Canyon in this stretch. Much of it is flat-topped. Exposures are numerous along its steep scarp. Almost without ex-

ception the gravel is foreset-bedded, and almost without exception this foreset bedding dips *up* the Snake River Valley. The amount of gravel not derived from the Columbia basalt in most sections does not exceed 1 per cent. The pebbles are worn, well sorted, and progressively smaller with increasing distance *up* the Snake. At the upstream terminus of the great terrace, a mile west of Riparia (Fig. 4), all the material is fine enough for highway gravel. The summit here is about 150 feet above the Snake. Though the Snake descends westward, the terrace top descends eastward.

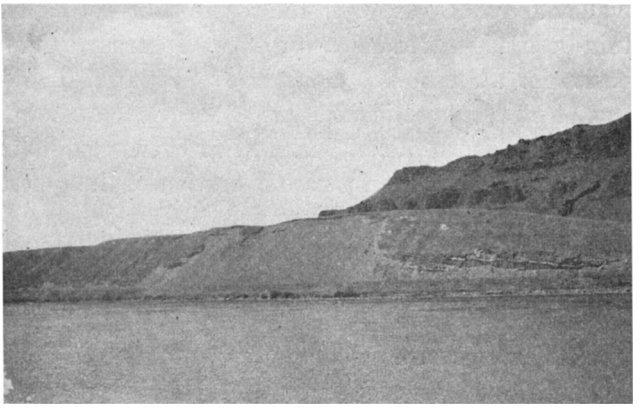

FIG. 4.—Upstream terminus of the Riparia terrace. Foreset beds dip to the right, or up the Snake, parallel with the terminal slope.

There is a terrace on the south side of the Snake comparable to the one described except that its extent along the canyon is much less. Another gravel deposit on the south side, also opposite the great terrace, lies in the mouth of the tributary valley of Tucannon River. Its surface is lower than that of the great terrace and descends southward *up* the Tucannon Valley to Starbuck, a distance of 4 miles. Here it meets the bottom of the pre-Spokane Tucannon Valley, descending toward the Snake. The stratification of the basaltic gravel of this deposit is inclined, and the dip is *up* the tributary. The material is progressively finer, also, as the distance from the Snake is greater. Some of the gravel apparently was carried into the lower part of Tucannon Valley from the east, across the angle

between the Tucannon and the Snake, but most of it came up the Tucannon.[1]

These three remnants of a great gravel deposit in Snake River Valley indicate

1) a supply of river gravel introduced some miles below Riparia and Starbuck, and carried eastward up the Snake and Tucannon valleys,

2) a depth of ponded water at Riparia of about 250 feet, and

3) the basalt plateau as the source of the gravel.

This deposit was made rapidly, else Snake River would have filled its valley above Riparia with the coarse débris of its hundreds of mountain-born, high-gradient tributaries. There is no evidence of such deposits for at least 100 miles above Riparia. The ponded Snake, if 250 feet deep at Riparia, was 50 feet deep at Lewiston.

Nothing on the south side of Snake River even suggests that the gravel of these terraces came from that portion of the plateau. On the contrary, the features of Tucannon Valley below Starbuck indicate that the débris came from the northern side, which bears the scablands.

Between Palouse River and Devils Canyon.—There are many large gravel deposits in this stretch, all falling into two groups: great rounded mounds, and flat-topped terraces. The great mounds are strictly only half-mounds, for they rest against the canyon walls somewhat like alluvial fans. Almost all of them occur on the inside of the broad curves of the canyon's course. Almost all of them slope from their summit contact, at the base of a basalt cliff, down toward the middle of the valley. These slopes are all convex. Where there is no notable cliff back of the mound, the gravel deposit has a convex top and is highest a little out in the valley. One such deposit lies like a great dam across the mouth of a tributary valley, and a narrow gash has been cut by that tributary subsequently. These half-mounds stand 150 to 200 feet above the river-level, and in the scarps cut by the Snake the gravel descends to river-level. In com-

[1] I. C. Russell (U.S. Geol. Survey, *Water Supply Paper* No. 4. p. 21) noted this gravel deposit in the Tucannon valley below Starbuck and interpreted it as Snake River gravel carried back up the tributary valley. He noted also great gravel deposits in the Snake Canyon. His interpretation is couched in the conventional terms of overloading of the main stream by excess supply from the headwaters.

position, they are 99 per cent Columbia basalt. Their structure is largely foreset, with the dip consistently *down* the canyon. They bear almost no gullies, ravines, or other erosional slopes except the steep riverward faces. Some of the mounds show a horizontal fluting and a minor mounding on their slopes which can only be original, depositional outlines, as, indeed, the convex slopes are original slopes.

The deposits of this group are bars. They were deposited during one short episode when the stream was deeper than they are high, yet had a mid-current velocity sufficient to keep most of the channel open from side to side and from top to bottom. The flood in which they were built came from the surface of the plateau, carried almost nothing but basaltic débris, and entered the Snake Canyon somewhere above the stretch in which they occur. This flood subsided so quickly that there was almost no modification of their outlines by either erosion or deposition from the lowering stream. Hillside and roadside gullies often show similar phenomena in miniature after torrential rains.

Only two flat-topped terraces were seen in this part of Snake Canyon. One is on the south side, opposite the mouth of Devils Canyon, the other is at Davin Station, on the north side, a few miles below the mouth of Palouse River. The summits of both are well above the tops of the mounded bars, the one on the south side 350 feet above the Snake, the one at Davin 200 to 250 feet above. Both are composed of basaltic gravel from top to bottom and scarcely touched by gullies.

In brief, then, the features of Snake River Valley for a few miles both up and down stream from the mouth of Palouse River indicate the entrance at that place of a great river from the north, far surpassing the proportions of either the Palouse or the Snake of today. The volume of this river actually ponded the Snake for 100 miles or so upstream, and into this pond was built a deltaic gravel deposit, reaching to Starbuck in the tributary Tucannon and nearly to Riparia in the main valley. And it is here, at the mouth of Palouse River, that the greatest contribution from the Spokane flood across the plateau scabland entered Snake River. The evidence for this has been presented in a previous paper and will not be reviewed

here. The glacial river at its inception was 10 or 15 miles wide, and in its central portion it eroded at least 500 feet deep just above its junction with the Snake. The Davin terrace lies at the debouchure of a distributary course of this river, and the plateau scabland extends almost to the brink of the Snake Canyon here. In a similar fashion the great terrace below Riparia can be traced northward to the scabland along the eastern margin of the wide glacial river.

Mouth of Devils Canyon.—Devils Canyon was eroded by overflow from Washtucna Coulee across a preglacial divide to Snake River Canyon during the Spokane epoch. As shown by the scarped loessial hills margining this glacial river course, the flood rose to 1,300 feet A.T. in Washtucna Coulee, at which altitude part of it spilled over to the deeper valley, and the large torrential stream thus formed rapidly eroded Devils Canyon. Before the close of the episode, the canyon was gashed 500 feet deep in basalt, all but cutting the divide down to the floor of Washtucna Coulee. The spill-over apparently entered a short preglacial tributary of Snake River, for the mouth of Devils Canyon is flaring, unlike the extreme narrowness of the rest of it. In the middle of this flaring mouth is a basalt knob, of no remarkable proportions, but characteristically a scabland knob, and flanked by post-Spokane talus. It is clearly an erosional remnant of the pre-Spokane floor of the tributary. Below this knob, and projecting in part out into the Snake Valley beyond the line of the canyon walls, is a gravel deposit about 160 feet above the level of Snake River. The surface of this deposit bears an exceptional ridge, shaped in ground plan like a horseshoe, with the concavity facing up Devils Canyon and the two ends abutting against the walls of the flaring mouth. The middle of this semicircular ridge is about 60 feet above the rest of the gravel deposit. It is symmetrically lower on both limbs, the lowest places being next to the rock walls. The slopes of the ridge are gentler toward the concavity, i.e., upstream, than they are toward Snake River. Post-Spokane run-off has cut a narrow ravine through the ridge at its contact with the eastern rock wall,[1] but when the glacial river ceased to flow,

[1] The topographer who sketched this ridge was quite at sea as to its origin. The Connell sheet shows it as a minor ridge projecting from the west wall of Devils Canyon and due to stream erosion.

this semicircular ridge was complete and inclosed a basin in the mouth of Devils Canyon. In this basin stood the eroded basalt knob above noted.

Closer scrutiny of the ridge shows that it is fluted radially, or composed of low radially elongated mounds, largely coalesced, and that on its downstream face, out in Snake River Valley, are traces of larger, older flutings on which the semicircular ridge has been built.

This curious gravel ridge is a bar. It is identical with the bars formed across torrential streams where there is a slackening of velocity because of increased width of channel and decreased gradient. It is duplicated in roadside gutters after heavy rains. It is evidence conclusive that a great torrent made Devils Canyon, that that torrent abruptly ceased to flow, and that the surface of Snake River at that time was more than 220 feet above its present summer level. The fact that the gravel deposit extends down almost to the river-level shows that Snake Canyon was then eroded approximately to present depth and the stream at that time was more than 220 feet deep.

The materials of the gravel deposit are not well shown. In the exposures available, the gravel is poorly sorted and little worn. It is practically all basalt. The large amount of interstitial silt in the gravel suggests its derivation from the destruction of loessial hills on the scablands farther north.

Snake River Junction.—In many ways the vicinity of Snake River Junction[1] exhibits the remarkable changes caused by the Spokane flood better than any other place in the canyon. An observer standing on the hilltop centrally located in Section 11, T. 10 N., R. 33 E. (Fig. 5), $2\frac{1}{2}$ miles southeast of the junction, can see for miles both up and down the valley. The canyon proper, with very steep, rugged, bare cliffs and ledges, lies below a broad higher valley floor that is several times as wide as the top of the canyon. Above this broad floor rise the gently rolling loessial hills of the plateau, but almost without exception their slopes toward the broad floor are about 30.°

[1] Junction of Spokane, Portland and Seattle Railroad and Lewiston branch of Northern Pacific Railroad.

The severely eroded bare basalt below the higher broad floor, typical scabland in its character, carries great isolated gravel deposits with rounded summits and convex slopes. The higher floor is 1,000 feet A.T. in maximum elevation at Snake River Junction, where it is determined by the upper surface of the Columbia basalt formation, from which the loess has been removed by the wide

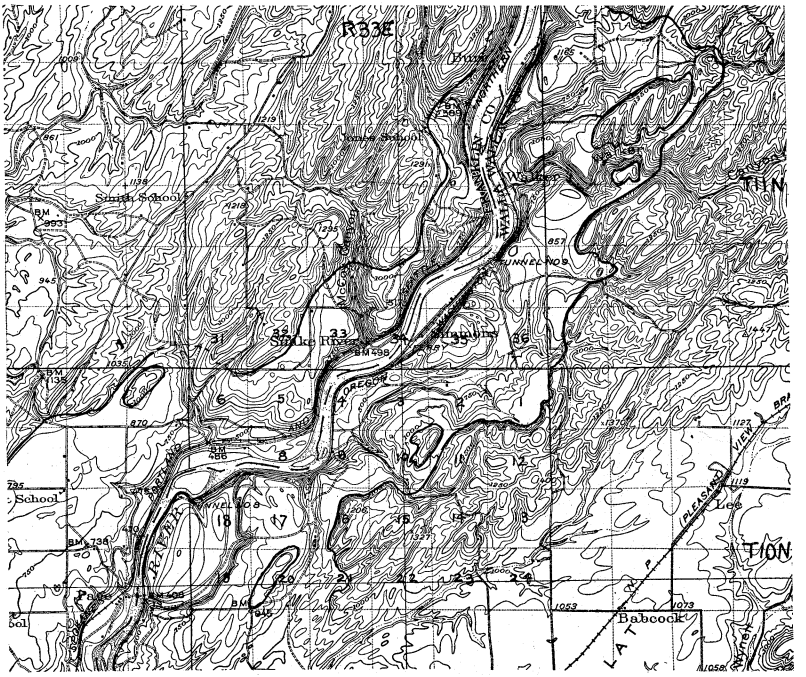

FIG. 5.—Vicinity of Snake River Junction, showing the loess-covered plateau, the extent of the upper floor of scabland basalt from which the loess has been removed, its steep margining slopes of loess, isolated hills of loess, and the abandoned portions of Snake River Canyon. From the Wallula, Washington, topographic map, U.S. Geological Survey.

glacial river, and on which gravel has been spread. The absence of such a floor from Riparia down to the vicinity of Snake River Junction is due to the failure of the flood to reach the upper limit of the basalt cliffs.

In the extreme northwest corner of Section 11, above noted, is an isolated loess hill, with slopes of 30°, with elongation parallel to

the Snake Canyon and with a prow pointing up the canyon (Fig. 6). Between it and the hill, centrally located in this section, is a flat-bottomed valley, walled by loess bluffs and floored by Columbia basalt at about 1,025 feet A.T. Here a small part of the glacial flood spread across a minor divide of the invaded loessial drainage system, to re-enter the main flood about a mile farther down. This isolated hill is typical of hundreds in the plateau scabland.

But at the cornering of sections 1, 2, 11, and 12 is another small preglacial valley in loess, similarly oriented and proportioned and with similar altitude of floor, but with the divide at the head intact. The divide is composed of loess and lies a little above 1,100. We

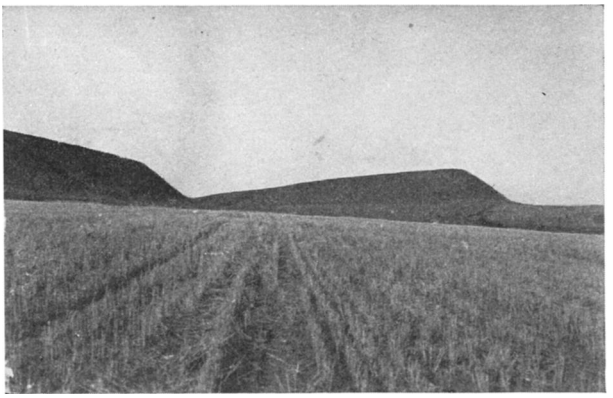

FIG. 6.—Isolated hill of loess, 2½ miles southeast of Snake River Junction

conclude, therefore, that the glacial flood which swept the loess from Section 1 and made the steep cliff in loess along its southern margin failed to rise to 1,100 feet A.T.

East of Simmons Station is a greatly eroded hill of nearly bare basalt (Sec. 35, T. 11 N., R. 33 E.), its summit a little below 1,100, with Snake River on the northwest side and a valley in basalt on the east fully as broad as the Snake Canyon but 250 feet less in depth. On the downstream end of the hill is a bar of basaltic gravel 250 feet thick. The broad streamless valley east of the hill is a part of the pre-Spokane course of Snake River, the stream having located and eroded a more direct route during the flood which so greatly denuded the basalt hill. This abandoned portion contains remnants

of a stained and indurated river gravel, of which not more than 25 per cent was derived from the underlying formation.

A great bar along the Spokane, Portland and Seattle Railroad, $2\frac{1}{2}$ miles northeast of Snake River Junction, is 400 feet thick. The gravel pit excavated by the railroad here has a scarp 200 feet high. The gravel is unindurated and slides easily, so that the structure is difficult to decipher. But it is 99 per cent basalt.

One more feature in the vicinity of Snake River Junction may be described and the list then closed, though every mile of the canyon here contributes to the history of the Spokane flood. The locality is between Page Station of the Spokane, Portland and Seattle Railroad and Tunnel No. 8 on the Oregon-Washington Railroad, and involves 4 square miles, most of it east of the river. The canyon here is narrower than at any other place in the plateau. East of the narrow place is a basalt hill 400 feet above river-level, possessing the typical severely scrubbed scabland aspect. The hill is separated from the rest of the higher land to the east by an abandoned valley which is open to the Snake at Tunnel No. 8 and opposite Page. Its floor is nearly 150 feet above the present river. Depending from the downstream end of the bare rock hill and overlying it in part is a gravel bar about 200 feet thick, whose convex outlines are unmistakable. The growth of the bar has constricted the southern part of the abandoned valley. The present course of the Snake through the exceptionally narrow canyon west of the hill departs from the fairly symmetrical meandering pattern it elsewhere possesses in the vicinity of Snake River Junction. Were the narrow canyon filled, the bar removed, and the Snake replaced in the old course east of the scabland hill, the symmetry would be restored, all steeper bluffs would stand on the outside of curves with the river undercutting them. and a uniform width of valley would exist throughout. It seems probable that the Spokane flood, which at its inception was at least 250 feet deep over the top of this hill, cut across a pre-Spokane spur in the valley's course and eroded the narrow canyon west of the hill. If this be correct, then Snake River Canyon was deepened here about 150 feet by the glacial stream.

In summary, the vicinity of Snake River Junction records a river of dimensions so great that the pre-Spokane valley was but a

channel for it. The glacial waters, in prodigious volume, reached at least 1,000 feet A.T., though the surface of the river today is but 400 feet A.T. here. About 150 feet of deepening in basalt occurred, all exposed rock slopes were greatly eroded to typical scabland forms, two new routes were cut across the pre-existing curves, huge amounts of basaltic gravel were eroded and transported. All the features of the plateau scabland are here. Bluffs of loess 250 feet high and with 30° slopes face the broad scabland floor, isolated prow-pointed hills of loess stand on the margins of the broad floor, bars of basaltic gravel with the typical convex slopes so often seen in the plateau scablands lie in protected places below the level of the broad floor, and cliffs without streams at their bases have talus standing three-fourths of the height of the original cliffs. The glacial river was at least 400 feet deep and 3 miles wide here at its inception.

THE SPOKANE FLOOD IN COLUMBIA VALLEY ABOVE THE MOUTH OF SNAKE RIVER

Columbia Valley between the limits reached by the Spokane ice sheet and the mouth of Snake River has not been studied as carefully as it deserves. But enough is known to warrant the statement that nothing comparable to the Spokane features of Snake River Canyon is found in it. No great bars are known, no bluffs of loess, no relocations of the stream course, almost no scablands. Yet the flood was there and left its record.

Columbia Valley is deeper and considerably wider than Snake Canyon, and carried its share of the Spokane flood without rising to the summit of the basalt cliffs. Hence the absence of the steepened slopes in loess and of scabland above and margining the river valley. Much of the water entering it passed through settling-basins which trapped the waste of the scablands. Much came directly from the margin of the ice sheet. The basaltic gravel which did enter appears to have been mingled with older gravel, and the striking dominance of basalt, seen in Snake River bars, is absent here. Evidence of the height reached by the flood has been found largely in the features of the scabland spillways from the plateau.

Moses Coulee.—The largest single spillway was Moses Coulee, a pre-Spokane drainage way which was greatly modified during the

Spokane epoch. In Columbia Valley at its mouth, and extending back up the coulee, is a gravel deposit more than 300 feet thick, the highest part of which is 925 feet A.T. and the lowest surface about 800. Since the coulee carried some discharge from the Wisconsin ice sheet, subsequent to the Spokane glaciation, this lower surface, which floors most of the mouth of the coulee, may not date from the earlier epoch. But the higher part certainly does. And below the mouth of Moses Coulee the high gravel terrace lies against the foot of an exceptionally high steep cliff of basalt. The cliff strikingly truncates a number of short tributaries to the Columbia and their separating spurs. It constitutes the east side of Columbia Valley and of Moses Coulee, and thus is traceable into the scablands. Only a great stream undercutting at about 1,000 feet A.T. could make this cliff, and the character of its talus dates it as Spokane in age.

"*The Potholes.*"—Ten miles south of the mouth of Moses Coulee is "The Potholes," a huge alcove caused by retreat of a scabland cataract. Not considering the remarkable holes, which are more than 125 feet deep in bedrock, the cataract made a sheer leap of 200 feet from the brink of the Columbia cliffs to the surface of a prominent rock terrace of the Columbia Valley, itself about 400 feet above the river. Over the edge of this terrace the stream spread in several channels and leaped again, this time about 125 feet. Much less work was done by the cataract on the edge of the terrace than on the summit of the cliffs, and for this notable difference a reason must be found. The terrace extends northward from "The Potholes" along Columbia Valley for several miles, rising upstream about 80 feet to the mile with the gentle tilt of the basalt flow which holds it up. For 2 miles north of the ancient cataract, the surface of the terrace is greatly channeled in typical scabland fashion, with "holes" and rock islands in complex profusion.[1] East of this scabland on the terrace top is the upper cliff with three-fourths talus.

Farther north, however, the terrace surface bears no scabland, and the cliff has soil-covered talus to the very summit. The Spokane flood, therefore, entered on this southward-sloping rock terrace at an

[1] Some of these are shown on the Quincy sheet, but most of them are too small to be caught by any contour.

altitude of about 1,200 feet A.T., scored its surface, and undercut the cliff above it. The three-fourths talus of this cliff indicates that all the wastage has accumulated since the scablands were formed. But 1,200 is the altitude of the brink of the upper Potholes cataract. No cataract existed, then, at the beginning of the spill-over. Its development waited until the main Columbia Valley flood subsided, though the scabland flood was still running at full volume. The explanation for this seems to be that some constriction farther down the Columbia Valley held up the great flood at first, but was rapidly eroded during the episode. The surface of the stream therefore fell until, late in the cataract's history, the rock terrace was exposed and the lower falls took origin. Such a constriction exists, and is described in this paper.

Gable Butte and Gable Mountain.—Near the towns of Hanford and White Bluffs, 35 miles above the junction of Snake and Columbia rivers, the Columbia Valley is 15 miles wide. Most of the valley floor here lies about 500 feet A.T., though the river surface is below 375. This 500-foot floor consists of a great gravel deposit which extends southward to and beyond the mouth of Snake River. This broad part of the Columbia Valley is largely structural, the basalt dipping below the bottom of the river channel. But near Hanford two large hills of basalt stand in the gravel plain (Fig. 7). They are parts of the north limb of an anticline which pitches eastward beneath the valley from the high basalt hills to the west. Gable Butte rises 763 feet A.T., or about 250 feet above the plain. Gable Mountain has two summits, one of them 1,075 feet A.T., the other 1,116, and the plain surrounding the mountain is as low as 425 feet A.T. Both hills have been greatly scoured and carry the scabland type of knobs and channels. The channels cut across the summits and vary in depth from 50 feet to 150 feet. Trenching the surface of the gravel plain about the base of the hills are much larger channels. They flank the hills in such a fashion that it is clear that the waters which scoured the hills developed the margining channels. The surface of the Spokane flood, therefore, rose above 1,100 feet in this wide valley.[1]

[1] Olaf Jenkins, in *Bull. 26, Div. Geology, Dept. Conservation and Development, State of Washington,* notes that the channels in the plain record a great glacial stream in the valley.

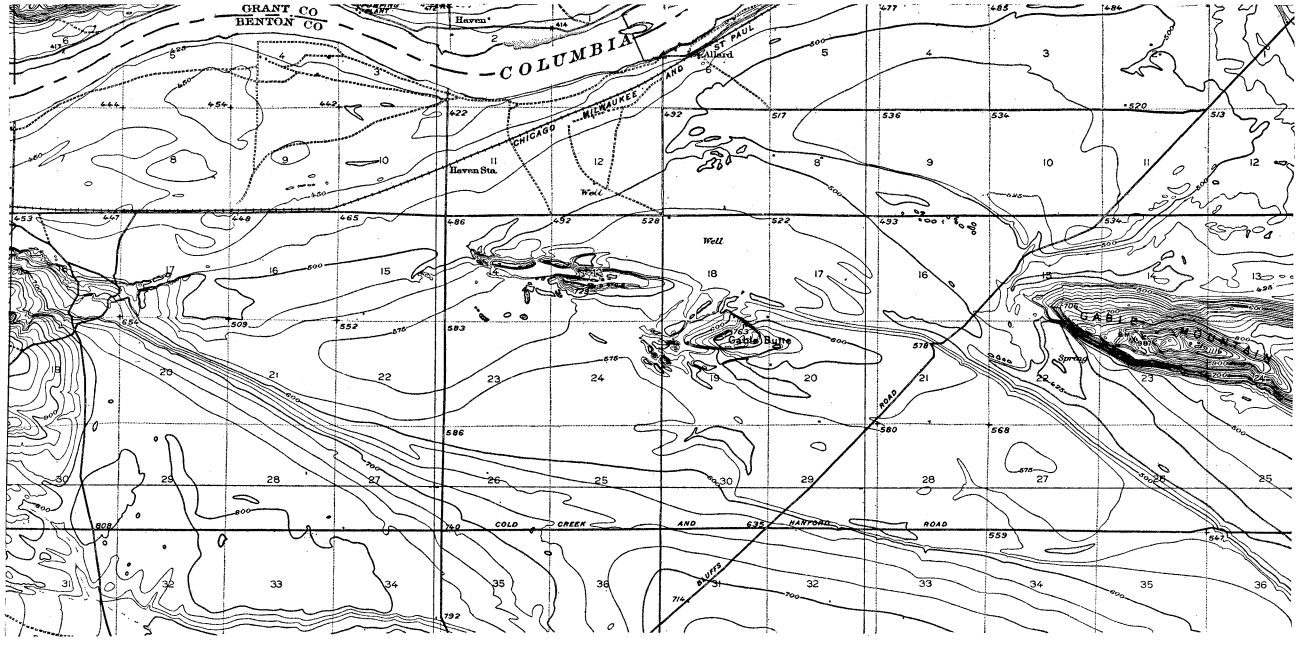

FIG. 7.—Gable Butte, Gable Mountain, and associated channels in the flanking gravel deposits. From the Coyote Rapids, Washington, topographic map, U.S. Geological Survey.

That the gravel plain flooring the wide valley is a deposit of this stream is not clear. Its surface is greatly obscured by sand dunes, and of its expression before they grew, only the large channels remain. Its materials include a large percentage of non-basaltic material. Its altitude is far below the surface of the flood. Yet it may be a gravel floor built where the wide valley invited deposition at the bottom of the great stream. If not, it is older than Spokane, rather than younger, as its trenching shows.

Othello Channels distributaries.—At the east end of Saddle Mountain, near Othello, part of the scabland flood on the plateau spilled southward over a pre-Spokane divide and took several distributary courses thence to both Snake Valley and Columbia Valley. At least four channels seem to have carried glacial water to the Columbia,[1] the northernmost entering in the latitude of White Bluffs and the southernmost mouthing at Ringold. Two of these open on the brink of the Columbia bluffs at 200 and 300 feet above the river, and two open back from the brink at altitudes of about 400 feet above the river, or 750 feet A.T. All of these altitudes are much below the upper limit of the flood as indicated by the rock terrace just north of "The Potholes" (1,200 ft. A.T.) and the summit of Gable Mountain (1,116 ft. A.T.). All are eroded in the weak Ringold silt and clay, which here constitutes the east bluff of the Columbia.

The relations of these channels and Gable Mountain seem to indicate the same situation as at "The Potholes": an initial great depth of water in Columbia Valley, and the lowering of that water-level while the scablands were being eroded. The differences in altitude of the channel mouths seem to indicate abandonment of some during the lowering of the Columbia and continued deepening of the remaining ones until the close of the episode. The gravel deposit at the mouth of Moses Coulee likewise records a late stage in the episode.

It is now in order to seek for the cause of the rapid lowering of the flooded Columbia during the Spokane epoch.

[1] Only the southern two were mapped in "The Channeled Scablands of the Columbia Plateau."

[*To be continued*]