VOLUME XXXVIII NUMBER 5

THE

JOURNAL OF GEOLOGY

July-August 1930

VALLEY DEPOSITS IMMEDIATELY WEST OF THE CHANNELED SCABLAND

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ABSTRACT

If a "Spokane Flood" ever occurred, and if the valley system of eastern and central Washington was already in existence, these valleys must have become channels and abnormal deposits of great magnitude must have been formed. This paper calls attention to such deposits along the western margin of the scabland—both in Columbia Valley, a main discharge route, and in Yakima Valley, a capacious tributary valley entering from an area unaffected by the flood. Three extraordinary situations are given especial attention: the mouth of Moses Coulee, the Columbia Valley deposits near Trinidad, and the truly astounding features in lower Yakima Valley. The conclusion is reached that nothing short of a catastrophic flood can explain these features. Skepticism can be justified only by the construction of workable alternatives.

The loess-mantled basalt plateau of eastern Washington possesses a system of linear anastomosing denuded tracts, the channeled scabland, in parts of which the basalt has been trenched in most unusual fashion. The writer has interpreted these linear tracts as abandoned river channels, rather than river valleys. From features of the anastomosing pattern, it was concluded also that most of the channels were contemporaneously occupied. These two ideas required the assumption of a volume of stream water greatly exceeding anything known elsewhere. Other data seemed to indicate that the great rivers were born suddenly, operated for a very brief time, and then abruptly ran dry. The term "flood" has been used to express this conception.

Doubt of the correctness of the writer's interpretation was early expressed, and several alternatives were suggested for the various peculiar features and combinations of features of the channeled scabland. In a paper considering these alternatives,[1] the writer noted that the flood hypothesis was not to stand or fall on data then in hand; that it could be critically tested by further field study. Certain relationships in unexamined areas must exist if it be correct and could not exist if it were incorrect. This paper deals with these relationships along the western margin of the main tract of channeled scabland. The areas considered are the Columbia Valley from Wenatchee River to Yakima River and the lower part of Yakima Valley.

COLUMBIA VALLEY FROM WENATCHEE TO THE MOUTH OF MOSES COULEE

In the paper above noted, it was stated that if the flood hypothesis is correct, Columbia Valley above the mouth of Moses Coulee must contain one of two types of record: (*a*) that of vigorous southward flow of an enormous glacial river whose surface descended from the edge of the ice to an altitude, at the junction, of from 600 to 700 feet above the present valley bottom, or (*b*) that of a backwater ponding produced by the great scabland rivers entering Columbia Valley at, and south of, Moses Coulee. If, on investigation, "neither of these exist, the hypothesis is fundamentally wrong."

The writer, after study of this part of the valley, concludes that neither record is present.

Obviously, the flood hypothesis must now be abandoned or the ultimatum must be retracted. If the latter alternative be followed, some special explanation must be devised for the absence of a flood record up the Columbia from the mouth of Moses Coulee.

No ingenuity is required to construct this special explanation on the basis of field evidence unknown when the ultimatum was made. Wenatchee River, draining from the high Cascades, enters the Columbia about 15 miles upstream from the mouth of Moses Coulee, and Columbia Valley between these two tributaries carries an unmistakable record of glaciation. Moraine topography extends down

[1] "Alternative Hypotheses for Channeled Scabland," *Jour. Geol.*, Vol. XXXVI (1928), pp. 193–223, 312–41.

the Columbia virtually to the entrance of the great coulee. Except that it is pre-Wisconsin, the age of this glaciation is unknown. To save the flood hypothesis, it is only necessary to assume that the glaciation was contemporaneous with, or subsequent to, the flood. The critical reader may object that advantage is being unfairly taken of gaps in our knowledge. The writer's reply is to counsel patience until the entire paper has been read.

The major features of Columbia Valley between Wenatchee and the mouth of Moses Coulee are determined by two formations, the Swauk shale and sandstone beneath the resistant Columbia River basalt. The dip is eastward, in the direction the river flows but more steeply. Thus the river has a wide valley in the Swauk formation for about 10 miles downstream from Wenatchee, overlooked on the north and south by converging basalt escarpments from 1,700 to 1,800 feet high (Fig. 1). About 5 miles above the mouth of Moses Coulee, the base of these escarpments comes down to river level and the valley thence downstream for many miles is narrow and deep, with precipitous walls of basalt. Rock Island Rapids is a mile or so within this narrow valley.

Rising westward with the dip, the contact of basalt on sandstone and shale, 7 or 8 miles west of Rock Island Rapids, comes up about 1,800 feet above river level. Here the steep cliffs of Columbia basalt above the contact are 2,000 feet high and the Swauk outcrop below, 4 or 5 miles wide, is marked by landslide topography, particularly on the south side of the river. There is no possibility of mistaking this landslide topography for moraine. But over the lower 500 or 600 feet of the Swauk outcrop area, foreign boulders and cobbles are not uncommon, though none were found with glacial markings. In the vicinity of Malaga and Mud Lake, from 7 to 8 miles below Wenatchee and on the south side of the river, good moraine topography is superposed on the lowest of the landslip features. The local relief of the moraine deposit itself is about 30 feet. As a mantle or thick smear, it extends from a flattish morainic terrace for 125 feet up on the landslide forms, culminating in a definite lateral moraine ridge 300 feet above the river. On the north side of the river, opposite Malaga, the morainic topography begins about 200 feet above the river and rises northward through 400

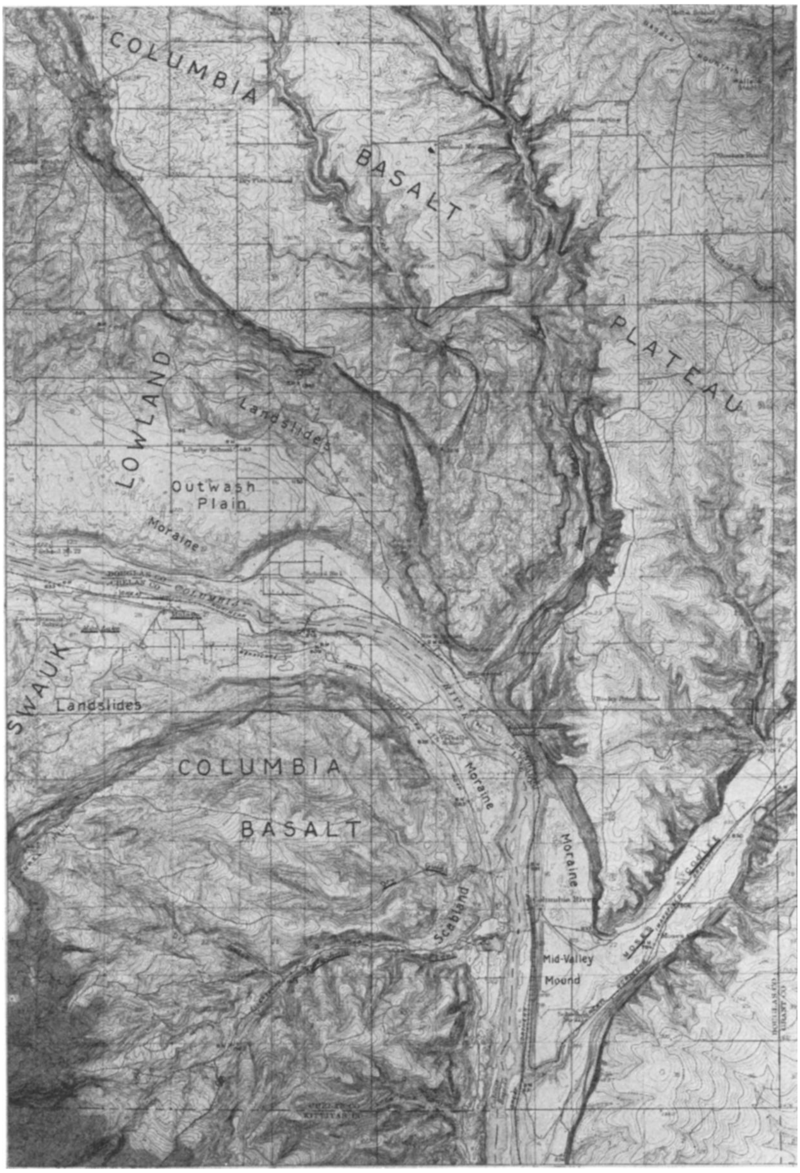

FIG. 1.—Malaga Quadrangle, Washington, United States Geological Survey

feet of altitude to a plain of outwash sand and gravel at from 1,200 to 1,250 feet A.T., 300 feet higher than the moraine on the south side and approximately as high as the foreign cobbles and boulders on that side. The outwash plain here is about a mile wide and slopes gently northward away from the moraine toward the lower exposed slopes of the Swauk. Some of the morainic ridges and associated linear undrained hollows are well shown on the Malaga sheet of the United States Geological Survey. They extend along the slope somewhat like landslip forms, but can hardly be confused with such. The maximum relief between a ridge and its associated sag on the uphill side is 125 feet.

The morainic topography downstream in the basalt-walled valley occurs only on the floor. The local relief between hillocks and adjacent undrained sags is about 30 feet. A stratified valley fill beneath the moraine consists in part of well-varved clay. The morainic débris is hardly 50 feet thick where shown in section just south of Rock Island Rapids. From this place the general moraine surface rises about a hundred feet in the next 2 miles downstream and there, without terminal ridging, ends abruptly against, or apparently against, an enormous deposit of débris at the mouth of Moses Coulee, a deposit higher than the moraine and of quite different character.

Though the upper limit of morainic material in this part of Columbia Valley is not sharply marked, present data indicate that it descends about 450 feet in 10 miles. The river in that distance, including the rapids, descends less than 50 feet.

The composition of these morainic forms near Malaga is not the physically heterogeneous stony and bouldery clay commonly termed till. Instead, the material is gravel, the fragments worn by running water instead of glacial ice and the finer constituents simply filling voids among the pebbles, cobbles, and boulders. Some sections show a poor stratification and sorting. It looks as though glacial ice had encountered great quantities of river gravel in this stretch and had re-worked it to make a morainic material largely devoid of clay and without evidence of glacial abrasion. Similar very gravelly moraine has been seen in the Rocky Mountain Trench at Polson and in the Purcell Trench north of Lake Coeur d'Alene, both places affording the possibility of glacial re-working of large stream-gravel deposits.

The content of basalt in this gravelly waste changes remarkably along the valley length considered. Near Mud Lake and Malaga, basalt constitutes from 30 to 35 per cent of the material. Three miles farther downstream, in the lee of some basalt hills that appear to be huge slide blocks out in the valley, the moraine hillocks are littered with large fragments of that rock, and 2 miles still farther downstream (at the rapids) the morainic débris is 85 per cent basalt,

Whether this ice came down the Wenatchee or Columbia valleys. or both, is not yet known. The first alternative seems most likely. Whether it was contemporaneous with the great scabland-making episode or was later is not yet determined. It seems, however, to provide a logical explanation for the absence of any record of Spokane Flood waters above the mouth of Moses Coulee.

COLUMBIA VALLEY AT THE MOUTH OF MOSES COULEE

A huge flat-topped mound of coarse detritus stands out in the middle of Columbia Valley at the junction of the great dry valley of Moses Coulee, the westernmost of the scabland river channels. The Columbia here is crowded against the west wall of the valley and confined to a narrow trench 350 feet below the highest part of the mound.

The mound occupies two-thirds of the valley width. Its summit area is triangular in outline, the highest part constituting an acute angle pointing up the Columbia Valley (Fig. 2). From this summit, its surface descends 50 feet per mile toward the south and southeast to the ravine draining out of Moses Coulee. But both sides of the acute angle are steep bluffs, the northeastern one descending about 50 feet to the moraine and the western one descending 350 feet to the Columbia. The western bluff is certainly river-cut. The northeastern bluff is either river-cut or an ice-contact slope related to the glacier that came this far down the Columbia. The gentle southern and southeastern slope is constructional. The mound summit is 350 feet above the river, 100 feet above the lowest place between it and the rock wall to the northeast, and about 150 feet above the ravine to the southeast.

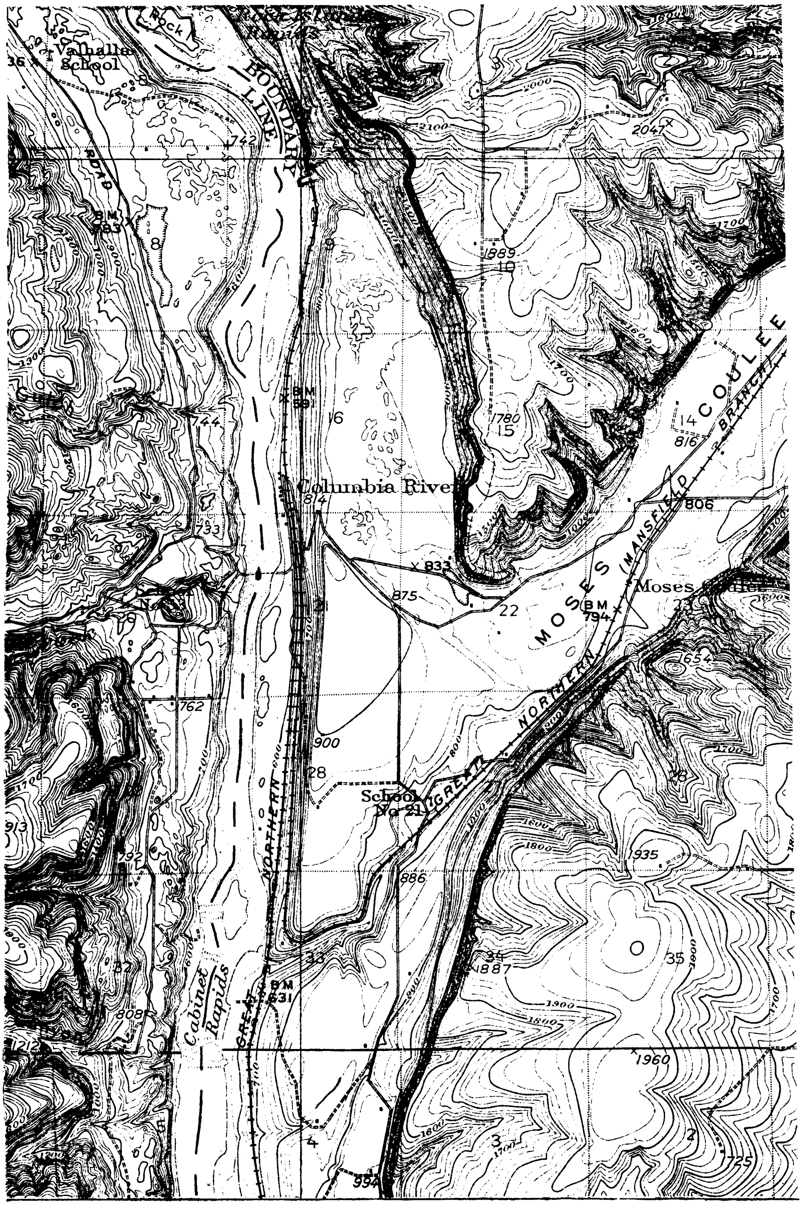

FIG. 2.—Junction of Columbia Valley and Moses Coulee; part of Malaga Quadrangle, Washington, United States Geological Survey.

There are no rock outcrops in the 350-foot western bluff or in the ravine from Moses Coulee. The material is apparently coarse gravel and boulders from top to bottom. Wells farther up Moses Coulee show corresponding depths of gravel below a floor approximately as high as the mound summit.

This mounded deposit, standing nearly in the middle of Columbia Valley at the mouth of Moses Coulee and undefended by any rock knob, is far higher above river level than any other deposit out in the valley for many miles upstream. It is alone as a mid-valley mound of débris; all other deposits in such position are terrace forms.

A plausible suggestion is that the location of the deposit is in some way related to the mouthing of Moses Coulee. Wenatchee Valley is comparable to Moses Coulee in width and depth, but there is no such deposit in the master valley at its mouth. Perhaps, therefore, different events in these two tributary valleys are indicated. Since Moses Coulee drains only from the basalt plateau, débris derived from it should be predominantly basaltic (though glacial ice on the north edge of the plateau might contribute some non-basalt). Columbia Valley receives drainage from a great variety of rocks, and its débris should be exceedingly varied. This criterion seems worth applying to the great mounded deposit.

Columbia River gravel now in transit rarely shows basalt higher than 50 per cent. This is true well below Moses Coulee, in the narrow basalt-floored and basalt-walled valley. No nearby tributaries from non-basalt areas are responsible for this proportion; it is due to non-basaltic débris brought down the Columbia past the mouth of Moses Coulee. Gravel of older terraces of Columbia Valley about Wenatchee and upstream show perhaps one-fourth basalt. The same proportions hold for the younger terraces, probably Wisconsin in age.

But the great mound is from 90 to 99 per cent basalt! This startling fact indicates clearly that the deposit consists almost wholly of débris from Moses Coulee, and that Columbia River has contributed little or nothing to it. If one considers again its remarkable proportions and its location out in mid-valley, it is difficult to escape the conclusion that Columbia Valley has been almost completely blocked here at some time by very coarse débris from a now dry tributary canyon. It is not difficult to visualize a complete temporary blocking and to devise criteria by which that idea might be tested. If the Columbia's trench along the west side of the mound has been cut 350 feet deep in an originally continuous fill of basaltic débris, there might be remnants still lingering on the west side of the river, remnants identifiable by altitude, composition, and structure.

Two minor tributary valleys from the west enter the Columbia opposite the great mound. Both contain valley-mouth deposits of gravel which have obviously caused relocation of the stream courses on buried rock shoulders. Both streams enter and cascade through short, steep-walled gorges within half a mile of the Columbia. In both, the deposit is limited to the valley mouth; it does not extend back up the tributary.

The deposit in the valley of the southern tributary, Colocham Creek, reaches 1,000 feet A.T., 75 feet higher than the summit of the mound across the river. That in Dry Gulch is about 100 feet above the mound summit. In both, the débris is from 90 to 99 per cent basalt. This would be expected in tributaries draining, as these do, entirely from basalt country. But in both the foresets dip back into the mouths of the tributary valleys, out of the Columbia and toward its western wall. These features seem to require some special explanation; they should not exist in Columbia River gravel deposits.

A further anomalous feature is found in the shapes of the gravelly fragments. In contrast with Columbia River gravel, which is well worn, most of this débris is sharply angular. Extraordinarily thin blades and long jagged slivers of basalt are very common. Rounded surfaces are present, but most fragments possessing them also have some sharp, hackly, fractured surfaces in addition. Such pebbles show clearly that they were originally rounded, were then broken by sharp blows, and promptly thereafter came to rest. The sharpness of fractured outlines of both broken-round and wholly angular fragments absolutely debars the idea of ordinary travel along any watercourse after the breaking.

The deposit in the mouth of Dry Gulch extends as a terrace-like form about a mile farther north along the Columbia Valley wall, its surface descending nearly 100 feet in that distance. This is as difficult to explain as a Columbia Valley feature as are the items already listed. It is perfectly in harmony with the picture of a great deposit from Moses Coulee blocking Columbia Valley. It needs only foreset bedding with dip up the Columbia to make it complete. Unfortunately, no exposures of its structure were found. Higher than this terrace are fragmentary remains of gravel deposits dominantly non-basalt. These seem to record much earlier Columbia River gravel, antedating even the last 700 feet of erosion into basalt, all of which occurred before the basaltic gravel deposit was made.

If one again takes stock of the data to see what other credit items for the Spokane Flood hypothesis should exist here, he finds that erosional forms apparently recording such an extraordinary episode are reported for Moses Coulee alone. He asks logically for scabland features on the west wall of Columbia Valley here, produced by the great flood which is hypothecated for the deposits. That scabland exists. It lies between the two tributary valley mouths and below about 1,250 feet A.T. A flattish basalt ledge here, a mile long and about half a mile wide, has been swept clean of mantle rock,[1] and the bare basalt has been notably roughened into crags and buttes and rock basins that show well on the Malaga sheet. A steep cliff rises back of this scabland ledge, a cliff which clearly is a truncated shoulder, formerly rounded and much less steep. Except for this cliff, virtually all slopes above 1,250 feet have a graded waste cover and are marked by normal drainage forms.

Moses Coulee has been pictured in the writer's earlier papers on scabland as a preglacial drainage line heading about 50 miles to the northward on the plateau and amazingly eroded later by glacial waters. A great ragged, dry cataract, 400 feet high and 1 mile wide, crosses the coulee about 20 miles above its mouth; huge bar-shaped gravel deposits occur throughout a vertical range of 300 to 350 feet on the greatly scoured lower slopes; and a major tributary, Douglas Coulee, entering the main canyon about 16 miles above the mouth, hangs 350 feet above the gravel floor and 550 feet above

[1] Deposition of dust and disruption of basalt have started a new mantle.

the rock floor at its point of entrance. Many minor hanging valleys are shown on the Malaga sheet. Much of this hanging condition of tributaries, which surely were adjusted to the preglacial valley floor, appears to be due to sapping of the coulee walls and consequent widening by glacial waters.[1]

The relation of this Moses Coulee discharge to the valley glacier that once reached down the Columbia to the coulee mouth needs a few more words. So far as altitudes and topographic relations are concerned, one might picture the great mound as outwash material from this glacier, the accumulation having been built up from 50 to 100 feet higher than the morainic topography immediately behind it. The sag northeast of the mound summit might be considered a spillway from this ice. But by such an origin the great mounded deposit would have a large proportion, if not a dominant amount, of non-basalt in its débris and its imbricated and foreset structures would be directed down, not across, the Columbia.

It can hardly be argued that a Columbia Valley glacier extending down to this junction would yield so little water that Moses Coulee's normal share of the ice sheet's drainage across the plateau would have given it complete dominance over the Columbia discharge. There must be added to the coulee discharge a very great supply from some extraordinary source.

The history of Moses Coulee, therefore, appears to include an episode of tremendous discharge of glacial water down through a canyoned tributary to a Columbia Valley as deep then as now, remarkable cataract development and recession during the life of the enormous discharge, remarkable widening to make of the pre-existing valley an adequate channel for the glacial river, bar-building on a scale known elsewhere only in the channeled scabland of the Columbia Plateau, and the making of a mammoth bar completely

[1] The 400-foot cataract, however, records at least that amount of deepening immediately downstream from it. The cataract probably became higher as it receded. It began, therefore, somewhere near the junction of Douglas Coulee, as a relatively minor affair. Francis Canyon, shown on the Malaga sheet, does not hang above the gravel fill of Moses Coulee, but a dug well in mid-coulee a mile distant penetrated 300 feet of gravel without finding bedrock. Francis Canyon, therefore, does hang at least about 300 feet above the true bottom of Moses Coulee. Its gradient, projected to mid-coulee, would not be 100 feet below the surface of the gravel fill.

across the Columbia Valley at its mouth. That a long series of Pleistocene episodes was not involved in making these great changes (though other Pleistocene events have undoubtedly occurred here) is argued from the following items:

1. Douglas Coulee, which never received glacial water of any great amount, is a normal valley for the region and hangs far above the main coulee. Had interglacial stream erosion been an important factor in the deepening and widening of Moses Coulee, this tributary would not hang. The erosion in Moses Coulee, therefore, was done by glacial water.

2. Hanging tributaries, if by any chance the result of interglacial stream erosion along main drainage lines, would exist in Douglas Coulee, Rock Island Creek, and other canyons of the region.

3. A long-continued aggradation in Columbia Valley at the mouth of Moses Coulee would have mingled débris of the master stream throughout. The basaltic content then would have been about 50 per cent instead of from 90 to 99 per cent.

4. Foresets in the great deposit and in its remnants on the west side of the Columbia would not dip westward, as they do, across the master valley if the Moses Coulee glacial river had not completely dominated the Columbia at that time. Imbrication of the flattish cobbles also indicates that the transporting current came from Moses Coulee, not Columbia Valley.

5. Virtually the only identifiable Columbia River débris in the remnants west of the river are the few rounded pebbles and the somewhat more numerous broken rounds. These are about 50 per cent non-basalt. The sharply angular material is essentially all basalt. No normal stream work produces such percussion-broken chips and slivers, or breaks up its rolled forms in the fashion or to the extent that these broken rounds record. The rounds and broken rounds were probably derived from Columbia River gravel already on the valley floor when the flood occurred.

COLUMBIA VALLEY BETWEEN MOSES COULEE AND THE POTHOLES CATARACT

The great bar at the mouth of Moses Coulee was built largely on the northern side of the glacial torrent. Its gentle southern aggradational slope is the northern part of the glacial river channel floor at the close of the episode. The gravel, therefore, was thrown back up the Columbia 100 feet higher than it was left in mid-channel. The southern part of this subfluvial gravel deposit lies south of the ravine subsequently trenched in the middle of the old channel. Just south of the ravine, it rises from mid-valley to the base of the eastern cliffs through a vertical range of from 100 to 125 feet. A

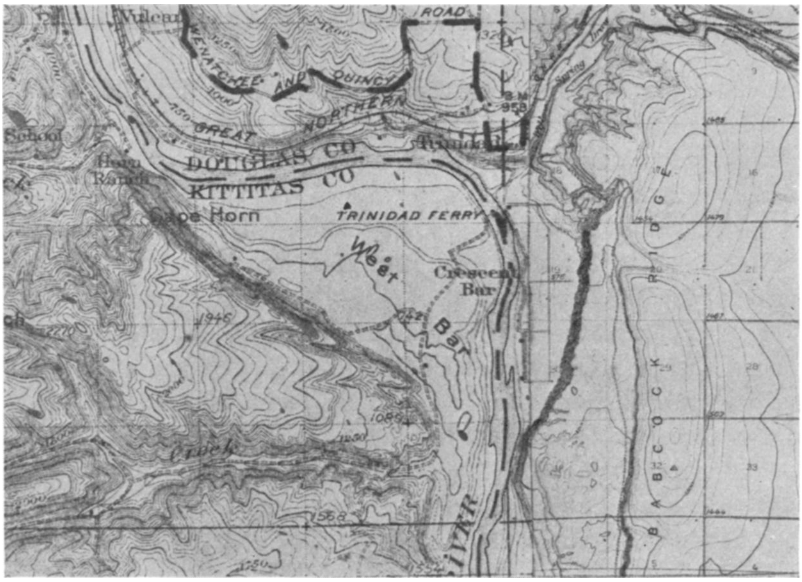

FIG. 3.—Vicinity of Trinidad, Washington. Parts of Colockum Pass, Washington, and Quincy, Washington, Quadrangles, United States Geological Survey.

terrace in this slope looks a bit confusing to this interpretation and will be dealt with later.

Four miles below the mouth of Moses Coulee, the Columbia turns sharply to the east for about 3 miles and then, at Trinidad, resumes its southward course (see Fig. 3). Northeast of the river, on the inside of the first curve noted, a thick gravel deposit extends from river level up to 1,100 feet A.T., a height of 550 feet. Nowhere does it have terrace forms. That it is a bar deposit still retaining the original form, except for obvious gullying, is shown in both topography and structure. Its structure is one of the most remarkable features to be reported in this paper.

The Colockum Pass map of the United States Geological Survey shows the highest part of this great gravel deposit as a compound lobate form depending diagonally down valley from the sharp turn in the basalt wall north of, and above, the gravel. The highest place in the deposit is a broad low mound half a mile long, lying nearly half a mile out in the valley and separated from the base of the rock wall to the north by a shallow fosse. On the north side of this mound, the gravel is foreset up the Columbia. The location is ideal for an eddy in a great stream filling the Columbia Valley from side to side at this altitude, and this low mound and its structure can be explained only by the conception of an eddy.

But the truly remarkable structure of this bar deposit is found in the riverward slope. The Great Northern Railroad has a large pit here, the cut bank of which is 200 feet or so high. Throughout this cut, the bedding dips *down to the west*, directly *up* the Columbia and parallel with the upvalley slope of the bar itself. In several places, there are lenses of short foresets in these dipping beds and the foresets dip *east*, *down* the Columbia, and against the dip of the gravel as a whole. They dip in toward the body of the deposit.

The writer has studied the structure of stream bars at every opportunity since he recognized these great scabland gravel mounds as genetically the same. He has found that flood-time bars, which become obliterated in large part before another flood and hence are essentially new constructions of each flood, commonly show stratification on all slopes parallel with those slopes. These bars, if properly placed, grow on the upstream side as well as laterally and downstream. Accretion on the upstream face thus produces inclined bedding which dips upstream, descending against the direction of the débris-bearing current. Unlike foresets, the material of such inclined beds has been moved up the slope.

The bar west of Trinidad, by this interpretation, was built by a current coming down the Columbia Valley. The predominant basaltic composition of all this banked-up gravel from Moses Coulee down to Trinidad indicates derivation from the tributary coulee, not the main Columbia Valley. Its change from very cobbly and bouldery gravel to material of railway ballast grades is perfectly logical. But to build this great deposit, a river must be sweeping over the total range in altitude simultaneously. The central current must be as deep as the bar is thick. If we measure from the base of the pit to the summit of the bar, that stream was 350 feet deep when the bar was growing on its upstream face. Up over that slope, the current dragged débris and added it until an equilibrium size for the eddy, or slacker place, in the current was attained.

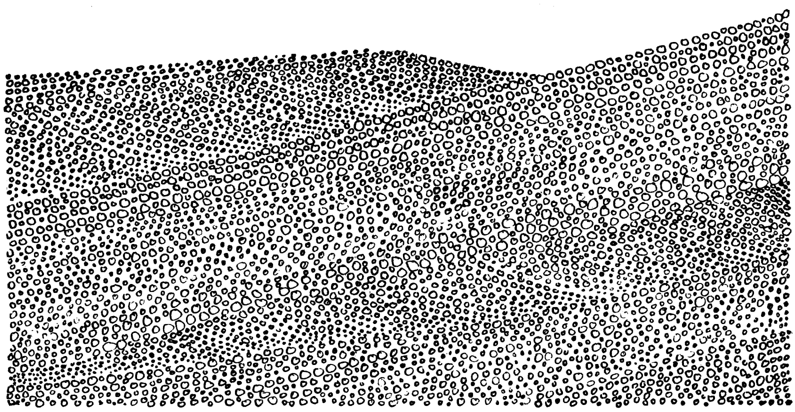

FIG. 4.—Diagram to show accretion on the upstream slope of a river bar and the development locally of current foresets dipping with the current but against the general structure and slope.

Locally, while sweeping gravel up this subfluvial slope, the current made downstream foresets which show by their dip, their gradation of material, and their decreasing amount of dip toward the lower ends of laminae that the current undeniably was moving along and up this slope (see Fig. 4). The central current was vigorous enough, after bar accumulation had filled in the slacker places, to keep the main channel from filling. Is there any other explanation for such structure and topography of a river-gravel deposit?

Another very instructive section exists in a second large pit, happily located at the downstream terminus of this bar deposit. Only coarse sand and fine gravel are exposed, well stratified and sorted. Here also the beds are dipping. But here the dip throughout is inclined toward the *east*, *down* the Columbia Valley. There are no current foresets in this; the dipping beds are more like long deltaic foresets. This section is in the lee face of the great side-channel bar, structurally, topographically, and texturally. It is not possible to make a fan or a delta of the deposit. Nor is it possible to make of it a series of accumulations during several distinct episodes of Pleistocene history.

The true vertical proportions of the bar, and therefore the maximum depth of the gigantic river debouching from Moses Coulee, are somewhat in doubt. The base of both pit sections is about 250 feet above the river. To include this 250 feet in the bar would hardly be justifiable in the absence of evidence below track level of the same character as that above. The Columbia undoubtedly has cut into the flood-gravel deposits. How much intrenchment has occurred here?

A bit of evidence which seems to bear on this question is found in West Bar, a terrace-like form from 150 to 250 feet above the river on the inside of the second curve noted and extending 4 miles down the Columbia below and across from the bar just described. The surface of West Bar ranges through 100 feet of altitude and is remarkably diversified with large hillocks of gravel. It completely blocks the mouth of Tekison Creek Valley from the west and the tributary has been forced to turn abruptly to the south and to go around the lower end of the deposit to reach the Columbia. Seen from viewpoints along the highway east of the river, the surface of West Bar seems to be marked by great current ripples. Since the top of the bar is at about the same altitude as the base of the pit sections, it seems fair to consider West Bar a part of the actual bed of the enormous glacial river at its closing stage. In such case the Columbia has cut about 200 feet here since the episode closed. The maximum depth of the river near Trinidad, by this view, was at least 350 feet. Since the curve in the river channel was not shared here by the western rock wall, the glacial current swung hard against the base of that wall and there was no opportunity for building a correlative of the thick side-channel bar that lies inside the first curve.

An erosional record of the glacial flooding in Columbia Valley near Trinidad should accompany the depositional record. Scabland forms, being essentially channel features, are better shown on flattish tracts than on cliff faces. We must look, therefore, for broader ledges along the Columbia at altitudes sufficiently low to have been overrun by the flood. Such ledges exist on both sides of the valley south of Trinidad. Those on the west flank the mouth of Tekison Creek Valley near the south end of West Bar. Here well-developed scabland extends up to 1,250 or 1,300 feet, from 750 to 800 feet above the Columbia. It consists of buttes, basins, and channels etched out of a bare rock terrace (a very thin soil is forming in some places) and a definite scarp rising from 100 to 150 feet higher to the west of the scoured bench. The scarp has a slope of about 27 degrees and truncates an older slope of about 12 degrees. Conspicuous remnants of the older slope, completely mantled with waste, descend toward the top of the steep scarp.

On the east side of the river is a very marked ledge of basalt, 1 mile wide in places, extending 16 miles along the river and rising from 900 feet at the south end to 1,375 feet A.T. at the north end. Most of it is shown on the Quincy sheet of the United States Geological Survey. The writer has previously described the features of this ledge, and they will be but briefly summarized here. The surface bears strongly expressed scabland, associated with small bar deposits. But this scabland is significantly limited to that portion of the ledge which lies below about 1,250 feet A.T. The northern and higher part is totally lacking in the bare-rock surfaces, the buttes, rock basins channels, and bar deposits of scabland. It also lacks the very steep cliff overlooking it on the east. North of the scabland-marked part of the ledge, the cliff has gentle slopes and, like the ledge, is mantled completely with soil. Whether one accepts the flood hypothesis for the origin of scabland or prefers some alternative, he must admit that subsequent to the erosion of Columbia Valley and the development of this marked ledge, some pronounced scouring has occurred over that part of the ledge below 1,250 to 1,300 feet and has not occurred above that altitude. The great bar deposit west of Trinidad is the highest known in this region. Though it falls 150 feet short of reaching to the scabland upper limit, its summit is higher than most of the scabland on the broad ledge. Furthermore, a spur of basalt ½ mile north and a little west of the

1,100-foot summit of the bar has been eroded into a jagged crest line at least 100 feet above the bar top. Closely associated with the largest notch in the spur is a mounded heap of basaltic débris thrown over into the ravine and interrupting its normal form. It seems probable that if one accepts the flood hypothesis for the bar, he must add the scabland-making to the episode and must therefore think of a river 500 feet deep.

CRATER CATARACT, NEAR TRINIDAD

The western part of the Quincy sheet shows three abandoned cataracts once used by glacial water escaping from Quincy Basin, in the plateau scabland, and entering the Columbia. In each the water above the brink reached essentially the same upper limit, from 1,275 to 1,300 feet A.T., and they must be considered as contemporaneous in action. This altitude is also that of the highest scabland on the broad ledge, and therefore no cataract spill could have occurred when the highest part of the ledge was scoured. Similarly, the scabland near the mouths of Colocham Creek and Tekison Creek is almost as high as the river surfaces just above the cataracts. The cataracts, therefore, must be a later development, and two episodes of scabland-making by glacial waters seem to be recorded. Several critics have urged the extreme improbability of the view that all scabland channels were contemporaneously occupied. Here is a critical place to test the idea.

Two of the cataracts (Frenchman Springs and The Potholes) poured directly over the wall of Columbia Valley on to the broad ledge, the deepest plunge pools (now dry) being 200 feet below the surface of the ledge. The northernmost fall (Crater Cataract) entered a tributary of the Columbia (Willow Creek Draw) about 2 miles upstream from the Columbia. It plunged from 1,200 to 1,000 feet A.T., and a flat-surfaced gravel fill at its base reaches thence nearly 3 miles to Trinidad, descending 50 feet in that distance and terminating in a bluff 400 feet high, now being undercut by the Columbia. The material of the fill is well exposed in numerous sections. It is composed of dominantly basaltic débris, little worn, ranging from sand to boulders but mostly a pebbly gravel. Its stratification is essentially horizontal. No foreset strata were found.

The gulch of Willow Springs Creek trenches buried rock spurs in a few places, but a creek valley as deep as at present existed here before the fill was made.

The brink of this flat valley fill is 250 feet higher than the scarped edge of West Bar 1 mile distant and 150 feet higher than the valley-wall contact of this bar, 2 miles distant. Yet the brink is 150 feet lower than the summit of the side-channel bar west of Trinidad. The topography and structure seem to rule it out of the bar category, yet its range in altitude includes that of the remarkable 200-foot section with bar structure only 2 miles farther up the Columbia. Its structure and cliffed terminus do not indicate a delta front; its gently descending gradient seems to require that it once extended farther out into Columbia Valley.

If this be true, the lower corrugated surface of West Bar, here interpreted as channel floor of the bar-building episode, must be younger. Yet the argument which ties the great bars into the episode of highest scabland-making requires Crater Cataract to function later and consequently the flat-topped Willow Springs fill to be the younger.

There are almost no terraces in Columbia Valley or in the mouths of tributary valleys for many miles upstream or downstream to use in determining age relations of this Willow Springs deposit to the bars. The only terracing of bar gravel known in the region occurs about 1 mile below the mouth of Moses Coulee. Here a scarp from 75 to 100 feet high interrupts the aggradational profile of the gravel deposit, the flattish tract below being about 850 feet A.T., 100 feet lower than the brink of the Willow Springs deposit. This scarp seems to be related to the Moses Coulee River, rather than to the Columbia, and is probably a record of channel-shifting beneath the stream surface in which the entire deposit was made.

The nearly complete absence of terraces on the bar profiles strongly suggests that the Willow Springs deposit is a product of special local conditions, and that it really belongs to the episode of tremendous discharge of glacial water across the scablands. This interpretation has at present no corroborative evidence to support it. The cataract and the filling in Willow Springs Draw still constitute a serious difficulty in the writer's interpretation of channeled scabland. The reader may consider that their existence disputes and perhaps denies such interpretation. This cannot be done, however, without a satisfactory alternative for the great gravel mounds and for the type of record shortly to be described for Yakima Valley.

COLUMBIA VALLEY BETWEEN FRENCHMAN HILLS AND SADDLE MOUNTAIN

Just below the southernmost of the three abandoned cataracts, Columbia River crosses the east-west Frenchman Hills anticline, a fold which lifts the surface east of the river an average of 400 feet and a maximum of 700 feet. Twelve miles farther south the river crosses another anticline, Saddle Mountain, parallel with Frenchman Hills. Its summit averages 1,000 feet above the broad sag between the two folds. An unnamed minor fold, about midway between these, lies in parallelism and therefore determines two minor structural valleys in the broader one. These structures, transected by the river, postdate its course. They strikingly controlled the course of glacial drainage across this part of the plateau and therefore predate the inauguration of glacial discharge. If this is correct, the Columbia Valley, throughout this stretch, and the structural valleys, where favorably situated, should also bear the characteristic erosional and depositional record. Examination has been made only near the two highways in this region, and the data therefore are fragmentary. The reader may judge whether or not they sustain the thesis of this paper.

Scabland exists along this stretch. There are no such favorable situations for its development as the broad ledge in front of the cataracts, and upper limits are difficult to determine on cliffs. The most prominent rock benches are in the transection of Frenchman Hills anticline. On the west side of the valley, scabland extends up to about 1,250 feet A.T. and has a youthful cliff back of it, like the scarps above scabland already described. The basalt flows here dip southward. If the cliff were the product of normal weathering and erosion on flows of differing resistance, it would follow the dip. Instead, this cliff retreats somewhat from the river and cuts the weaker flows above the bench at progressively higher horizons while maintaining its altitude. The scabland on the bench here is 750 feet above the river, yet very little subdued by the processes which are breaking down the buttes and filling the basins. The bench east of the river is about 1,200 feet A.T., very close to the upper limit apparently, since a pronounced and unequivocal development of channels, basins, and buttes is lacking.

At Vantage Bridge, 3 miles south of the transection of Frenchman Hills fold, no good bench exists and scabland cannot be positively identified above 1,150 feet on the cliffs.

The southern of the two minor structural valleys (now containing lower Crab Creek) carried a great glacial stream from the plateau to the Columbia, but, unlike the three spillways directly from Quincy Basin, it had no waterfall. Scabland features in this syncline at the base of the north-facing Saddle Mountain scarp have been described in an earlier paper. It will suffice here to note that the upper limit, determined about 12 miles back from the Columbia, is 1,100 feet A.T., though the preglacial structural valley there was at least 200 feet and probably 400 feet deep at that place. Glacial water was up nearly to 1,100 feet in the Columbia Valley to produce this. A similar record of the upper limit is found in the master valley for many miles downstream, yet there is indisputable evidence of great current action in many places up to this level. A current producing scabland forms of the magnitude of these, yet without apparent gradient for many miles downstream from the mouth of Crab Creek, is truly an extraordinary conception. Does not the idea literally condemn itself at the outset? But if the reader can be persuaded to read to the end of this paper, he will find that the field evidence at the mouth of Yakima Valley is as extraordinary as the conception, and that it will not permit any alternative of the flood hypothesis yet proposed.

There is a better record of deposition than of erosion by the flood water in Columbia Valley between the two anticlinal crossings. The North Central Highway from Ellensburg to Spokane descends into Columbia Valley from the west along Whisky Dick Canyon and crosses to the east side of the valley on Vantage Bridge. Coarse angular rubbly bar material lies as high as 1,000 feet A.T., 500 feet above the river, in the re-entrant containing the tributary canyon. It is mostly slope rubble collected locally, very little sorted, unworn, poorly stratified, and very rudely foreset-bedded in places. The foresets have various dips. Here and there the deposit contains clean basaltic sand lenses from 1 to 3 feet thick. Non-basaltic fragments are rare but present. They are most abundant near the upper limit of the deposit. Much of the basalt is decayed, but there is also fresh material intimately intermingled in all exposures. The

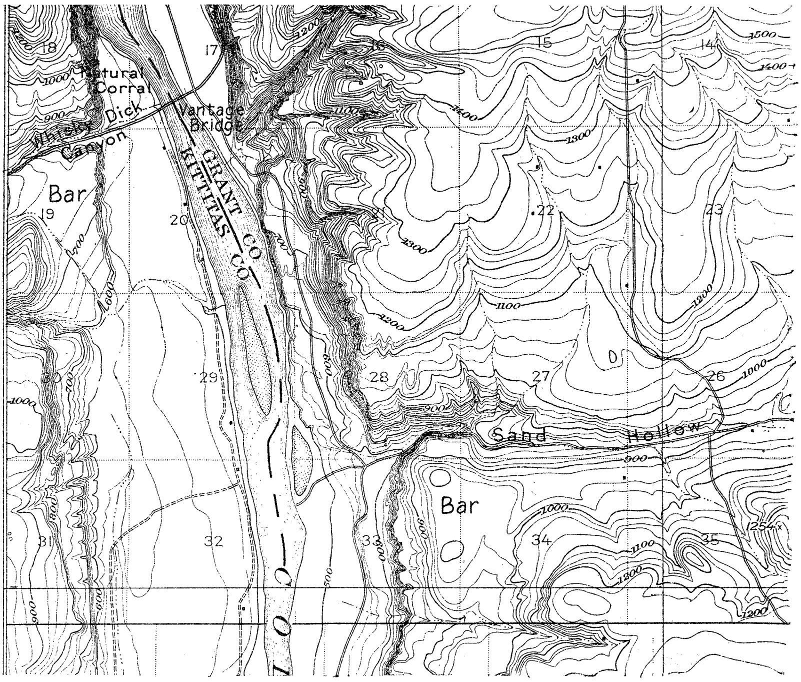

FIG. 5.—Columbia Valley just south of Frenchman Hills. From Quincy Quadrangle, United States Geological Survey.

deposit of little worn local material constitutes a complete barrier up to 700 or 750 feet, diverting the intermittent drainage off to both sides of the fill. Its riverward front is a cliff 175 feet high, cut subsequently by the Columbia. In form it suggests a huge fan built in the mouth of the tributary (see Fig. 5). A fan of these proportions, however, requires conditions that would be recorded in many, if not all, other tributaries of similar size and character in this stretch. No other tributary valley mouth deposits suggest fans.

Furthermore, the structure is quite wrong for a fan; the deposit contains material foreign to these basaltic slopes; and it extends down the Columbia along the face of the basalt cliffs far beyond the limits to which a fan from this valley could possibly grow. The original slopes of the deposit still exist in large part and are well shown on the Beverly sheet of the United States Geological Survey.

East of Vantage Bridge, the basalt cliffs are scored by many deeply gashed ravines or gulches. Virtually all of them contain irregularly disposed large mounds of angular bouldery and cobbly basalt débris, several once completely blocking the gulches. Their location prevailingly on the north sides of the gulches suggests that they are not so much a result of eddying back from the swollen main stream as of current sweeping across the spurs between gulches at, and above, the level of the deposits. One such deposit directly east of the bridge is 380 feet from base to summit. Its vertical range is not its thickness in any one section, for it lies throughout on the steep northern wall of the small coulee containing it. Original depositional slopes of these minor bars have been but little modified by subsequent drainage down the steep gulches. Foreign rock fragments occur in these deposits and scattered over the scabland surfaces up to about 1,150 feet A.T.

Sand Hollow, a small stream-eroded valley in the bottom of the northern minor structural valley, enters Columbia Valley about $2\frac{1}{2}$ miles south of Vantage Bridge. A large bar occupies the flaring mouth, constricting it below 1,000 feet A.T. to half the valley width above that altitude (Fig. 5). The bar summit is 200 feet above the valley bottom immediately upstream. Indeed, one must travel half the total length of this drainage way before the rising gulch floor is as high as this bar summit. The summit, moreover, is essentially in the middle of the flaring mouth. Later drainage has cut a narrow defile around or across the northern end of the deposit. The narrow cut descends 100 feet in about 2,000 feet horizontal, while above the bar the gradient is 35 feet a mile, about one-fourth as steep as in the defile. The bar summit includes about 200 acres and, somewhat lower, extends down the Columbia a mile beyond the mouth of Sand Hollow. Glacial water was up on the adjacent slopes at least 100 feet higher than the summit of the bar.

COLUMBIA VALLEY NEAR THE MOUTH OF YAKIMA RIVER

The great bar deposits in Columbia Valley for many miles south of Saddle Mountain gap have been described in earlier papers. Only one feature of this part of the master valley will be described here. It occurs on the west slope of the valley close to the northern base of the Rattlesnake Hills. The hills are the crest of a fold in the

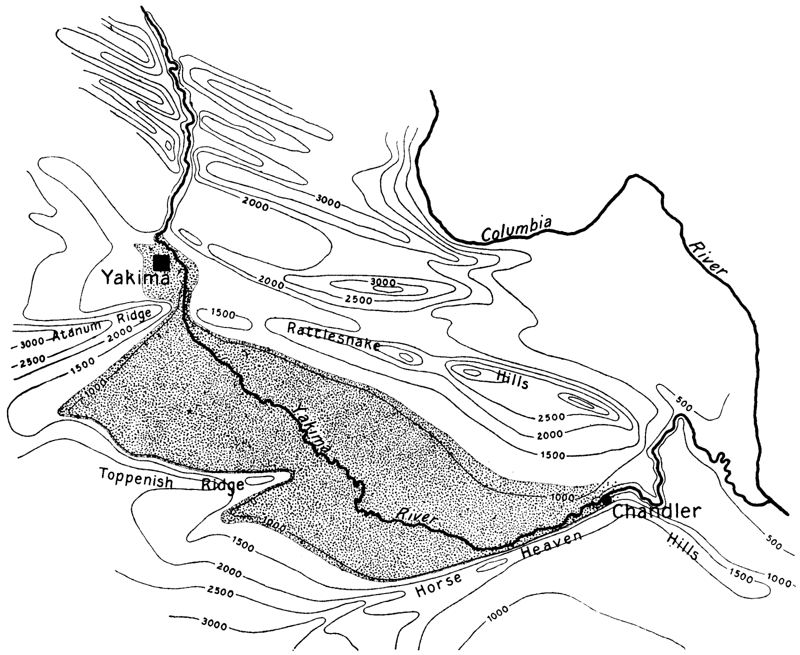

FIG. 6.—Lower Yakima Valley

Columbia basalt which trends northwest-southeast. The summits are as much as 3,000 feet above the river. Traced southeastward, the altitude decreases and the fold approaches close to the Columbia at Richland and Kennewick. Yakima River crosses a low place in the fold about 10 miles upstream from Richland. A dissected bench lies along the northeastern side of the Rattlesnake Hills below the steep descent from the crest. It abuts against the basalt fold at an altitude of about 1,500 feet A.T., from 1,000 to 1,100 feet above the Columbia. The bench is 10 miles long and from 2 to 4 miles wide (see Fig. 7). It resembles a piedmont waste slope as much as a terrace. Its range in altitude in any cross-section is from 750 to 800 feet. No outcrops were found to show its true character, but with this we are not at present concerned.

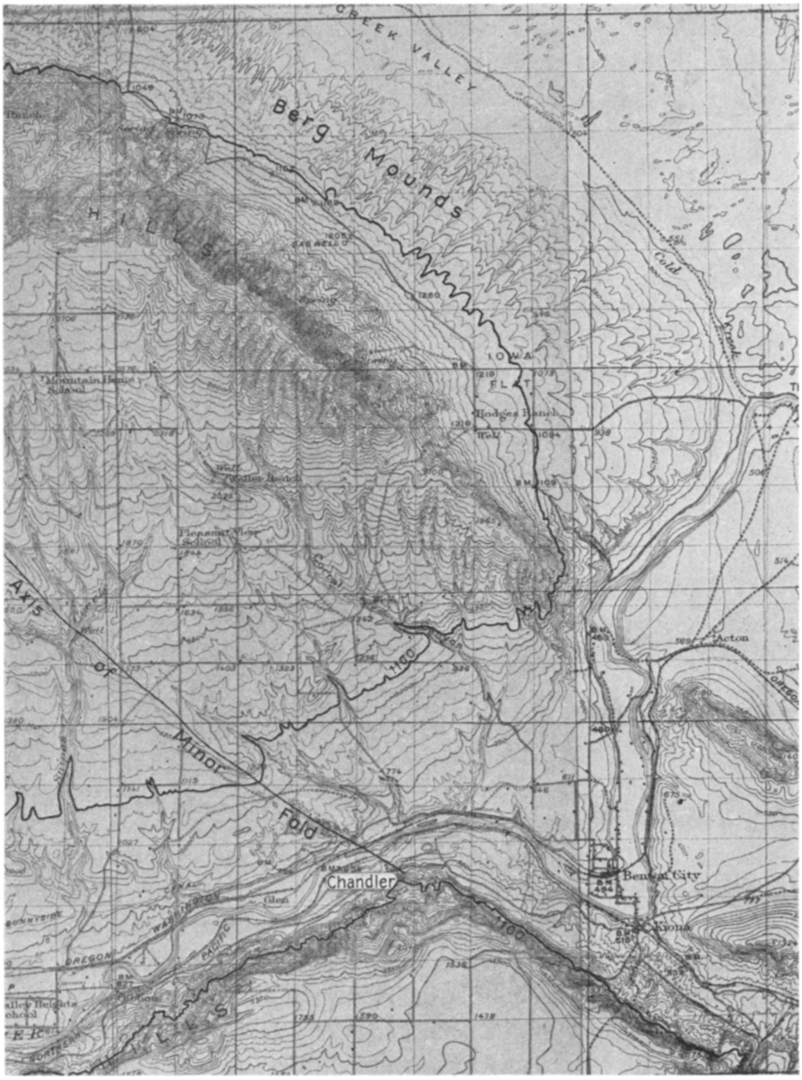

FIG. 7.—Vicinity of the mouth of Yakima Valley. Parts of Prosser and Pasco Quadrangles, United States Geological Survey.

Over the lower part of this sloping bench occur mounds of glacial débris from 10 to 20 feet high and 100 feet or so in diameter. A dozen or more can be seen from almost any viewpoint on the northern half of the sage-covered bench. There must be several hundred of them on the slope. They are distinct constructional forms and, in places, suggest a morainic topography, though there are no associated undrained depressions, no ridge forms, and no cover of drift on the tracts separating them.

These mounds are largest and most abundant below about 850 feet A.T. The slope above carries scattered foreign boulders up to 1,100 feet A.T. Above that altitude, glacial material is wholly lacking.

The débris in the mounds is essentially a till. Striated and smoothed surfaces are common on the fragments of fine-grained rocks. The striae are mostly short and somewhat out of parallelism. Not rarely they have slight curved or angular changes in direction.

The boulders and cobbles exhibit a highly varied assemblage of rock material. Granite is the most common constituent. Slate, argillite, and fine-grained quartzite are common also. The textures, colors, thinness of stratification, fineness of grain, and presence of mud cracks and ripple marks in these fragments suggest very strongly that they came from the glaciated mountains of Beltian rock in northern Idaho, northwestern Montana, and adjacent British Columbia. Another fairly common constituent is a granodiorite porphyry, identical in the hand specimen with berg-borne boulders of this rock in virtually every scabland channel on the plateau and back up several tributary valleys along the east side of the scabland.

Very little gneiss was found, though in British Columbia, directly north of this part of the scabland, gneiss is a very common bedrock.

Five of the six mounds examined in detail contained no Columbia basalt, though a trip of at least 75 miles and perhaps 250 miles across basalt country was necessary to bring this material here, and though Rattlesnake Hills, wholly of basalt, are only 3 miles distant and rise 3,000 feet above the mound-marked area. Derivation from ice on any part of the plateau seems debarred. So does mingling of local rock waste subsequent to deposition. Yet in one mound Columbia River basalt was very common. If it did not come from the waste of Rattlesnake Hills, it appears that some ice which melted here did contain Columbia basalt.

It seems obvious that these scattered mounds of till are great berg deposits. It seems probable that the bergs came across the scabland from the northeast. If so, they traveled at least 250 miles to reach this place. The abundance of the mounds indicates large numbers of bergs. The bulkiness of the mounds seems to bespeak bergs of enormous size.[1] If they were river-borne, great streams were required to transport them. Great abandoned glacial waterways from the northeast exist. Are they channels or valleys? If channels, were they ever filled with the enormous streams the writer conceives of? Is it only coincidence that the upper limit of this berg-borne material here is the same as that of the stream-eroded scabland in lower Crab Creek Valley, lower Snake River Valley, and Washtucna Coulee? These striking mounds on the northeast flank of Rattlesnake Hills cannot be dismissed from the problem of channeled scabland.

If these deposits are correctly interpreted as berg-laid, they must not be limited to this sloping bench in Columbia Valley. The interpretation here advanced is supported by isolated patches and mounds of berg-deposited till in many places throughout the plateau scablands and even in Columbia Valley beyond the scablands. Erratic boulders, which are more common, must mean the same thing.

It is significant that the United States Bureau of Soils map of Benton County, Washington, shows an abrupt change from one soil type to another on this bench along the 1,100-foot contour line. The subsoil profiles, as described, are notably different; that above 1,100 feet being unstratified and essentially pebbleless, while that below this altitude is stratified and with foreign pebbles, cobbles, and boulders common. The examination necessary for such a modern soil map is far more detailed than was the writer's reconnaissance. The map shows the same contact at the same altitude in Yakima Valley south of Rattlesnake Hills and, at a somewhat lower

[1] If the larger mounds are as thick as they are high, 5,000 tons is not too great an estimate of the weight of débris in one of them. If its true weight is only one-tenth of this, a berg $50 \times 50 \times 50$ feet in dimensions would be required to float it.

altitude, 75 miles farther down the Columbia. The berg-floated débris of south-central Washington does not occur above 1,100 feet in the extensive low area where Yakima, Snake, and Walla Walla rivers enter the Columbia.

This item is essential to the appraisal of an alternative hypothesis. Berg transportation does not require river currents. Bergs may drift widely in standing water. Such a submergence has been described for this region[1] with the statement that its upper limit was about 1,250 feet A.T. That altitude is attained farther north in Quincy Basin and the Columbia Valley west of it, but the region about the mouths of the Snake and Yakima seems to show, on restudy, that no berg-floated material occurs above about 1,100 feet. Consistently throughout the scabland region, the upper limit of erratic boulders is higher farther up the valleys. Yet this increasing altitude cannot be due to subsequent warping for three reasons. (1) A theoretical "unwarping" to bring all upper-limit erratics to a common level would almost completely remove all gradient from the valleys which contain the floated boulders, and which therefore are older than the berg-drifting. (2) Such warping to explain the rising gradient of upper limit must be regularly distributed along many rather diversely oriented glacial drainage ways. No causal relations for this seem thinkable, and coincidence seems a very far-fetched idea. (3) Tributary valleys which received backwater from the scabland do not show any upstream rise in upper limit of erratics. Warping, therefore, affected only the tracts used by glacial waters. This explanation is far from satisfactory.

If the field facts justify a conclusion, it is that the upper-limit gradient of berg deposits is associated genetically, and not by coincidence, with the corresponding upper limit of loessial scarps, scabland, and bar gravel. Nowhere in the region have these berg deposits been found too high to belong to the group.

YAKIMA VALLEY

There is no region more favorably situated than lower Yakima Valley (Fig. 6) for a crucial test of the flood hypothesis. It enters

[1] J Harlen Bretz, "The Late Pleistocene Submergence in the Columbia Valley of Oregon and Washington," *Jour. Geol.*, Vol. XXVII (1919), pp. 489–506.

the Columbia more than 600 feet below the upper limit of the berg-drift débris. For 70 miles above the mouth, it is a capacious structural valley, the folding of which antedates the highest records of the flood in the adjacent Columbia Valley. The point must not be missed that its floor has been aggraded, rather than degraded, by Yakima River since the valley was made and therefore that no high-level features in it can be ascribed to early stages in valley deepening. Unlike Columbia Valley above Moses Coulee mouth, lower Yakima Valley has not been glaciated. If the Spokane Flood occurred, this valley must have received a very marked back-rush into it from the main route of flood discharge. An unequivocal record of such a back-rush is a vital requirement of the hypothesis. Yakima Valley is especially significant as a test because it was not studied at any time during the development of the hypothesis, and therefore no part of that scheme was ever constructed to take care of whatever features it might contain.

As important as the structural origin, capacity, and low altitude of Yakima Valley is the fact that it is structurally constricted at its mouth by the convergence of the Rattlesnake upwarp on the north and the Horse Heaven upwarp on the south. At the significant altitude of 1,100 feet A.T., the valley narrows from an average of 15 miles to only 3 miles, at the station of Chandler.

Not alone does this narrowing constrict the valley cross-section, but a minor fold on the southern slope of the Rattlesnake Hills, shown in Figure 7, averaging perhaps 100 feet high, actually crosses over to the Horse Heaven flexure *through the Chandler Narrows*. Thus, in addition to the narrowing, the floor of the synclinal valley is raised at this place.

In further preparation for an understanding of Yakima Valley's record, the reader should note that the lowest place in the rim of the structural valley, by which glacial water backing up from the Columbia might conceivably have escaped is 1,476 feet, 376 feet higher than the 1,100-foot upper limit repeatedly referred to. Without an escape, the flooding back must come to a standstill by the time the valley is filled. Any up-valley current which might be recorded in Chandler Narrows could have existed *only while the valley was being filled.*

Except for the flood plain and low terraces, the floor and lower slopes of Yakima Valley are buried beneath a heavy deposit of pebbly, gritty silt, generally poorly stratified and sorted, and in places without stratification or assortment. It is identical in all respects with the deposit mantling the lower part of the bench with the berg mounds (the soil map shows it as the same soil type), mantling the slopes of Walla Walla Valley to the same limits, and

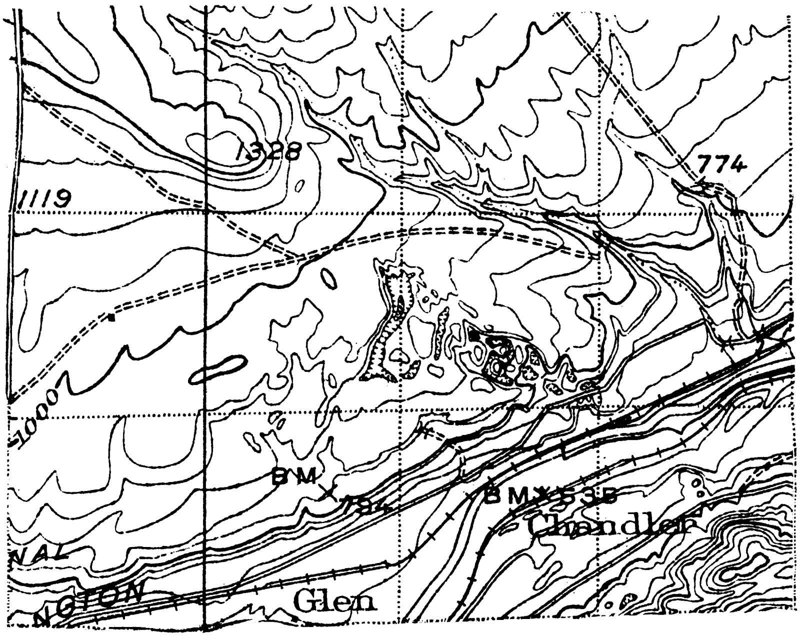

FIG. 8.—Chandler Narrows within the 1,100-foot contour

except, as to altitude, lying on the slopes of Snake River Valley and many minor valleys upstream from the scablands. Samples taken from many places show the same amazing proportions of all grade sizes from silt to fragments too large to collect, boulders in size. Boulders of Beltian rock and of the granodiorite porphyry are here. Bruises and glacial markings are common; subangular shapes are the rule.

Yet this anomalous sedimentary mantle does not go above about 1,100 feet A.T. either on the valley slopes or upstream along the valley length. Another structural enlargement, 30 miles north of Yakima (the Ellensburg part of the valley, 1,500 feet A.T. and higher) is totally lacking in the glacial deposit. This fact rules out the obvious alternative that valley glaciers once occupying the Yakima headwaters contributed the glacial silt. It came into lower Yakima Valley from the Columbia; it was transported upvalley.

The details of the Chandler Narrows must now be examined. Figure 8 shows the minor fold across the structural narrows, its

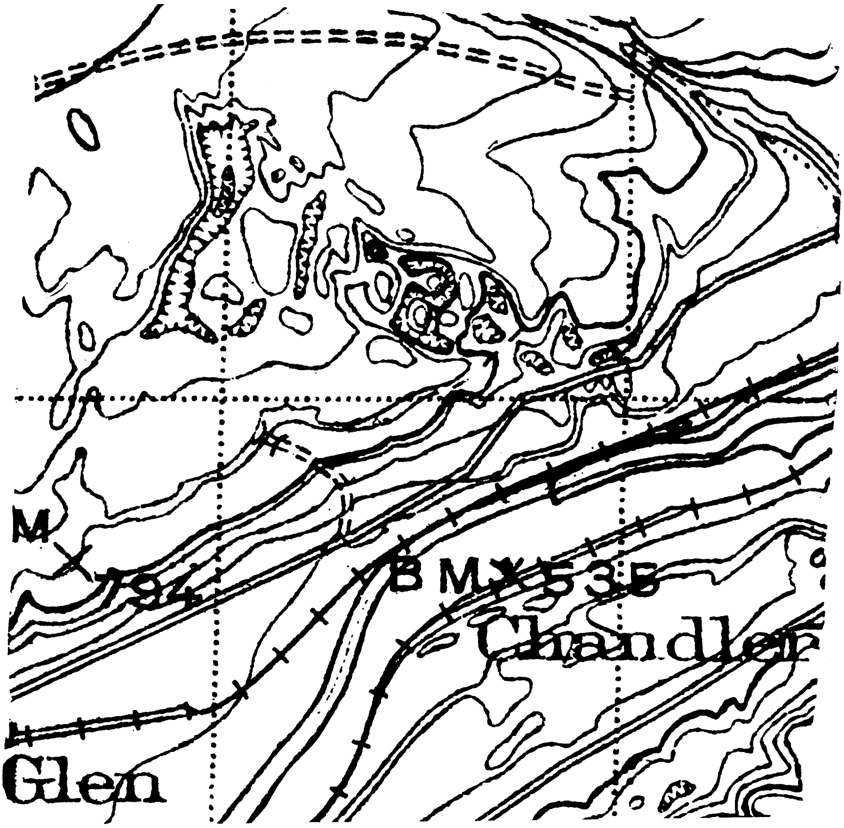

FIG. 9.—Chandler Narrows scabland

crest descending below 1,100 feet 1 mile north of the river. Closely paralleling it on the northeast is a normal erosional valley, consequent on the major structural slope. The crest of the minor fold below 1,100 feet bears a curious topography, wholly unlike anything else on the fold or on any other surfaces of the district. A closer view, magnified from the Prosser topographic map of the United States Geological Survey (Fig. 9), shows ten irregular undrained depressions irregularly distributed among a number of hillocks. One of the depressions is more than 100 feet deep (the two inner lines, though unhachured, are depression contours) and immediately adjacent to it is a hill 100 feet high, giving a total relief of more than 200 feet in about 500 feet horizontal. Another cliff, more than 150 feet high, rises from the bottom of the largest depression.

This curious irregular topography ranges along the crest of the fold from 950 down to 600 feet above sea-level, from 450 feet above the river to only 100 feet above. It looks like a group of sand dunes or kame piles enclosing associated depressions or a cluster of sink holes. But it is none of these.

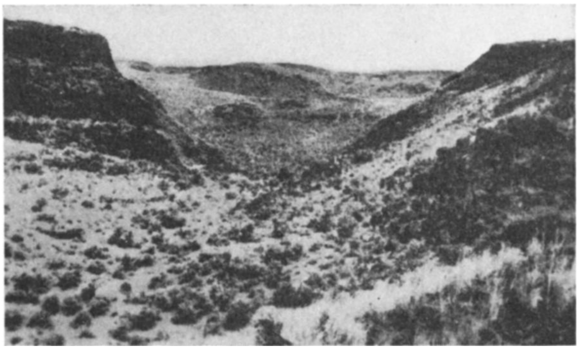

FIG. 10.—Rock basin 100 feet deep in Chandler Narrows scabland

The map alone will not solve our problem. Field examination yields the important information that the material fashioned into these sharply expressed holes and hillocks is basalt. The holes are rock basins; the hills are ragged eminences of tilted basalt flows. The problematical topography is an erosional topography in the crest of the fold below 950 feet A.T. (see Figs. 10 and 11).

Figure 12, a cross-section of Yakima Valley at Chandler, shows six different profiles: (1) the irregular topography of the crest of the fold with five rock basins in black; (2) a restoration of the original surface of the fold, drawn along its length; (3) the general structural slope alongside the minor fold; (4) the profile of the consequent tributary valley parallel with the fold; (5) the erosional valley of Yakima River in the bottom of the larger structure; and (6) the upper limit of the glacially derived material in Yakima Valley. The floor of the deepest basin (more than 100 feet deep) is 200 feet below the crag on one side, 250 feet (or nearly so) below the crag on the other side, and only 125 feet above the river. Excavation for the highest rock basin started 450 feet above the present river level and 275 feet above the structural valley floor. All basins lie in gashes cut essentially across the fold. One is cut as deep as the adjacent tributary valley and another one is almost as deep, though both are on the structural divide.

These features are scabland features, as great a departure from normal erosional features as anything on the plateau. Scabland of

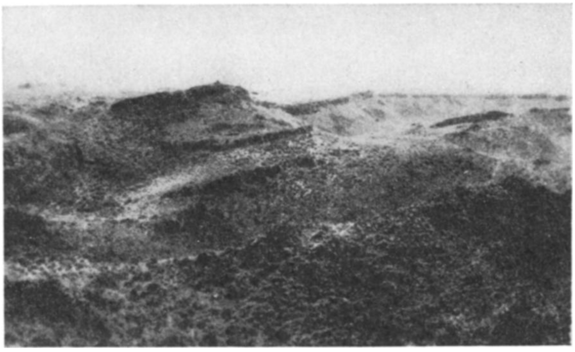

FIG. 11.—Dipping flows of the minor fold in Chandler Narrows scabland

lesser magnitude goes somewhat higher on this slope, but not quite to 1,100 feet. Chandler Narrows contains all the scabland there is in Yakima Valley, and it is significantly limited to the crest of the low fold which stood in the Narrows. Yakima River began trenching 275 feet below the uppermost of these rock basins and avoided the fold in all of its work. It cannot be held responsible. Local drainage has avoided the fold, cutting its valleys alongside, not across. One may well ask, "Is this truly erosional topography? May it not be due to collapse of lava caverns? May it not be the result of explosive vulcanism? If it is erosional, was running water the agent?"

The answer can be given from other data. The minor drainage ways down the southern slope of Rattlesnake Hills, from Corral

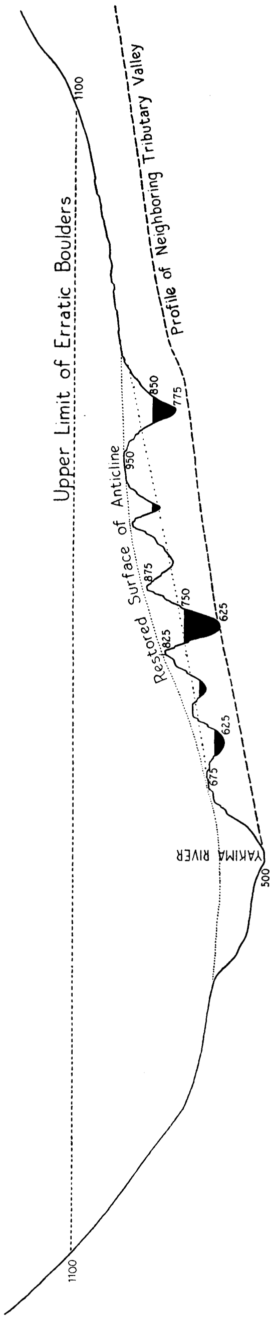

Fig. 12.—Cross-section of Yakima Valley through Chandler Narrows. Rock basins in black

Canyon on the east to Snipes Creek on the west (see Fig. 7), contain heavy deposits of little-worn gravel on their eastern sides, burying the rock walls and narrowing the valleys. The western walls lack the gravel deposits. In Corral Canyon, $3\frac{1}{2}$ miles east of the rock basins and buttes, the gravel deposit extends for 1 mile along the east wall and ranges from 700 to 800 feet A.T. In Snipes Creek Valley, $4\frac{1}{2}$ miles west of the scabland tract, this gravel buries at least $\frac{1}{2}$ mile of the eastern wall and ranges through 175 feet vertically, reaching close to 1,000 feet A.T.

These gravel deposits, well exposed in excavations, are extraordinarily bouldery in places. The boulders, cobbles, and pebbles are dominantly of basalt, very little worn to wholly angular, clearly shifted but little from the source and possessing an intimate mixture of weathered and fresh basalt throughout the total thickness. The weathered material was already altered before deposition occurred. The source yielded boulders of weathered basalt. Talus might have such a composition; so might glacial drift; but an agent which rolls its débris would soon destroy such fragments or their weathered exteriors. Sparingly distributed through the coarse basaltic waste are unweathered fragments of granite and well-rolled quartzite pebbles, derived locally from a gravelly member of the Ellensburg formation.

This gravel is foreset-bedded throughout in every exposure. The foresets without exception dip *up* Yakima Valley, *away from* Columbia Valley to which the Yakima is tributary. The action of flowing water is recorded, but its direction of flow was exactly the reverse of normal. The foresets (Fig. 13) are not long deltaic beds, but very irregularly disposed and interrupted and cut off by overlying foresets.

More gravel deposits exist among the scabland knobs and basins of Chandler Narrows. Here they occur as separate moundings on

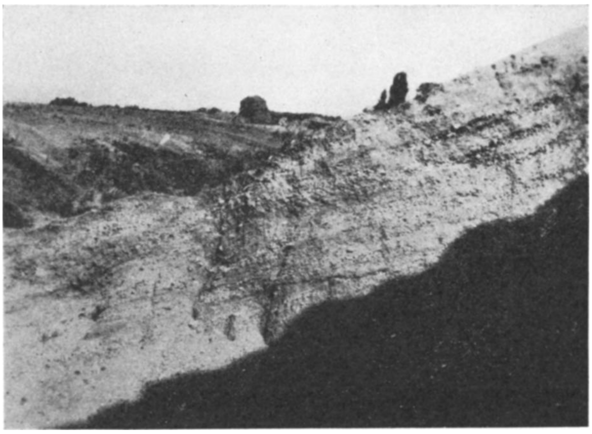

FIG. 13.—Foreset-bedded gravel on east wall of Corral Canyon, Yakima Valley, looking north.

the lee (upvalley!) side of buttes, in the rock basins and blocking subsequent drainage on the slopes of the group. One such bar stands 40 feet high in the bottom of the deepest rock basin and is composed largely of boulders which range up to 3 feet in diameter. Some bar forms stream upgrade westward out of rock basins and even beyond the eroded fold. There can be no reasonable doubt that the scabland and the gravel deposits of Chandler Narrows and vicinity are genetically associated. Little doubt need exist that the anomalous pebbly, sandy silt farther up the valley is also genetically associated. That the berg deposits up to 1,100 feet, both on the Rattlesnake Hills bench and throughout Yakima Valley, are a product of the same episode seems a perfectly fair conclusion. All of these features point to a source outside of Yakima Valley and a reverse current moving up the valley.

Lest one still hesitate to admit that these extraordinary phenomena demand the extraordinary origin imputed by the writer, let us examine another narrows in Yakima Valley; one which should have the same kind of a record if the glacial water and débris came down the Yakima Valley, and which should *not* have them if the writer's hypothesis is correct. This place is the Yakima Canyon between Yakima city and Ellensburg. Here the river has cut from 1,000 to 1,500 feet deep across several folds in the basalt to escape from the

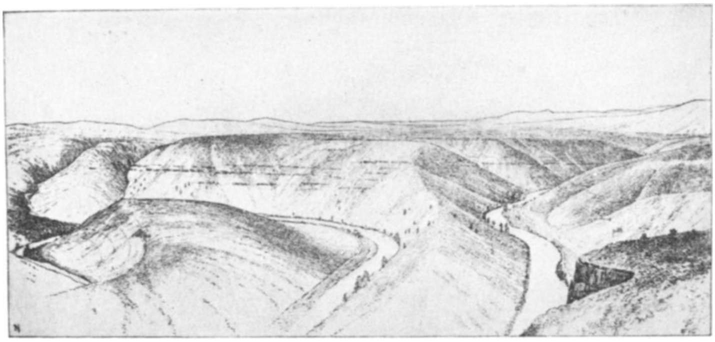

FIG. 14.—Yakima Canyon between Ellensburg and Yakima (from *Professional Paper 19,* U. S. Geological Survey).

Ellensburg structural valley and to enter the lower Yakima structural valley. The canyon is shown in the northwest corner of Figure 6, and a portion of it is shown in Figure 14. The narrowness is more pronounced than at Chandler, and this, with the winding course, should offer a much better opportunity for tremendous scour than does the Chandler constriction. But both the map and the sketch show no scabland whatever. All slopes are normal for a valley of this kind, steep cliffs outside the curves, virtually all slopes clothed with creeping waste, rock outcrops very limited, no gravel bars, no stream gravel at all except at the bottom, and that gravel occurring only in terraces. Much of the gravel exposed along the highway cuts possesses a reddened upper zone.

Whatever happened at Chandler Narrows never happened in Yakima Canyon. The floor is above 1,100 feet!

We have thus far reached the following conclusions:

1. The scabland on the minor fold in Chandler Narrows is a product of aqueous current along the major structural slopes.

2. The current action was subsequent to the trenching of Yakima River and its tributaries into the structural forms.

3. The current moved up Yakima Valley.

4. The current was tremendously effective at 950 feet, 450 feet above the present river.

5. No glacial water reached higher than 1,100 feet in Yakima Valley, 376 feet below the lowest place in the rim.

The capacity of Yakima Valley west of Chandler Narrows and below the 1,100-foot contour is 3.17 cubic miles. If there has been but one flooding of the valley with glacial water, that is the total quantity which, passing through Chandler Narrows, produced the features which have been described. The Columbia in maximum flood discharges 1,170,000 second-feet past The Dalles, about 150 miles down the river from the entrance of the Yakima. If such a flooded Columbia could be diverted into the mouth of Yakima Valley (by a blockade, let us suppose, in the Columbia canyon below the Yakima junction), it would fill Yakima Valley to 1,100 feet in about four and a half days. Any current so produced would be an uphill current, its velocity dependent on a surface gradient only and constantly decreasing as the cross-sectional area of the rising water in the Narrows increased. Since, however, Walla Walla Valley would also fill at the same time (it has the same records up to the same altitudes), the time for filling would be considerably longer than indicated in the foregoing, and the velocity would be correspondingly decreased.

What does the Columbia do today with this maximum flood over the same kind of rock, with a surface gradient of 20 feet to the mile? It has a velocity then of at least 15 miles an hour, perhaps 20 miles. The rate of erosion has not been determined, but that it is infinitesimal, compared with the erosion at Chandler Narrows, is obvious. Four and a half days of maximum flood past The Dalles have never made observable changes in the channel.

Only by tremendous velocity could a current from Columbia Valley produce these great erosional effects in Chandler Narrows by a single flooding. Such a velocity, if conceivable, can exist for only a small fraction of four and a half days. The only conceivable way to get these results by water flowing 450 feet above the river along the slopes of a structural valley 2 miles wide at this level is to allow an advancing *wall of water*, like a gigantic bore, to sweep through the Narrows. Only thus can this vertical range of rock basins of similar magnitude, plucked out of the anticlinal crest, be produced.

Would anyone care to argue for more than one flooding to do this work? The field evidence does not debar that. But no sum of less vigorous floodings, even though they reach as high, will explain the rock basins and the mounded bars. Enormous velocity is a prerequisite: enormous velocity over almost the whole wetted perimeter of the Narrows. The shorter the time, the greater the results. To the writer, the features of lower Yakima Valley constitute the final, complete, and irrefutable evidence that there was a Spokane Flood.

The writer, at least normally sensitive to adverse criticism, has no desire to invite attention simply by advocating extremely novel views. Back of the repeated assertion of the verity of the Spokane Flood lies a unique assemblage of erosional forms and glacial water deposits; an assemblage which can be resolved into a genetic scheme only if time be very short, volume very large, velocity very high, and erosion chiefly by plucking of the jointed basalt. The total published data now encompass virtually all phases of the episode and exceed what one may readily assimilate by reading alone. It is time for a field conference with those who still insist that normal quantities of glacial water, operating through several Pleistocene episodes, could produce the phenomena. The writer does not deny a long and complicated history; he simply insists that at some time in this history there was a catastrophic flooding across the scabland, down the Columbia, and back into pre-existing tributary valleys.