Bitterroot Valley, Montana. June 29 1929

A structural valley with nearly uniform width of 8 miles from Missoula south to Hamilton. Narrows south of Hamilton but retains trench-like character. No spurs. Mountain wall on west higher and more precipitous than on east. Very narrow gorges cut this slope. Cirques on the north slopes of the divides between and plenty of snow at this date this year. The western wall shows two facets at several places, an upper gentler slope from the summits down half way or so, and a considerably steeper slope thence down to the upper parts of the huge gravel fill in the structural valley.

The fill is largely dissected and removed, most of the valley containing only the floodplain and lower terraces of the Bitterroot River and gently sloping spurs and remnants of the big fill above them. At Florence, the old gravel constitutes shoulders and terrace remnants up to 3600 ft, perhaps 3700 ft. A.T. The gravel is not well worn. Near the mouths of larger tributaries, it is coarse cobbly gravel. Lower parts exposed in only one place seen; the bluff east of the river a mile north of Florence. Here it is a fine gravel and sand, with a few clayey members thru more than a hundred feet of thickness. Apparently this is the main river's deposit and the coarser material in the shoulders nearer the valley walls is locally derived from the high-gradient tributary streams off the adjacent mountains.

The lower part of the bluff noted has markedly stained gravel. Staining is a bright orange yellow and quite irregular. Apparently a ground water staining. No weathered zones or coloring in the section. Most of the material is almost white.

Older gravel in the shoulders and high terrace remnants ranges from 3300 to 3600 and perhaps 3700 and probably is thicker than that. Many tribs trenching this gravel deposit have broad, gently sloped valleys but others seem to be so loaded that they have done but little deepening. They simply descend the slope that the river, by its erosion of 300 to 400 feet in the deposit, has left.

All shapes of this gravel are normal erosional forms. There is nothing here to even suggest the valley-mouth bars of the Snake.

Records of Lake Missoula are very scanty. Definite shorelines exist only on spurs of the shoulders, elsewhere they are very faint tho readily detected at a distance. The spur east of the river bluff noted above has eight weak notches cut in a vertical range of 225 ft. The strongest of these has a steepened slope about 10 feet high above the old water line. But at the best, it is a weak feature. South of Florence, no shore lines were seen. Someone in the literature on Lake Missoula has reported them near Hamilton. Campbell There are no lake deposits associated with these shorelines. And none seen on the valley floor Possibly the silt deposit to be expected on the valley floor has been obliterated by subsequent stream work. Possibly silt once on the slopes has been washed off by subsequent slope wash, possibly the shore lines are recessional ones and the silt was removed by the lowering level of wave work. But if Lake Missoula was terminated by a bursting of the ice dam and a rapid draining, these shore lines are a record of the rising level, not the lowering.

No ice-rafted boulders identified on the shoulder above noted.

Under what conditions did Bitterroot Valley fill so deeply with gravel?

Why is this gravel so fresh close to the surface on the tops of the remaining ridges?

Missoula to Polson June 30 1929

The gravel flat on which the city of Missoula stands and which extends along the road to Polson for three or four miles is probably a post lake stream flat. There is no silt on it and no erosional shapes in it. This terrace is 88 ft, plus or minus, above the river. About five miles north of Missoula is an abandoned brick plant, the clay for which came from a deposit of silt that is at least 20 feet thick. The silt constitutes a rolling terrace 30 feet or so higher than the gravel flat. Its subdued scarp seems to be an old river bluff eroded in the silt. Material is a pale pinkish tan, very well stratified, uniformly fine silt without gravel or sand members. It is clearly and definitely varved.

This is the Lake Missoula silt. It once was a continuous fill and Clark Fork has since removed most of it.

More of this silt at intervals but only low down in the valley. Large eroded remnants of the big gravel fill seen south of Missoula yesterday here constitute shoulders 300 feet high. There are also lower terraces in the fill. But all evidence visible indicated that no silt mantle covers these terraces or lies on the shoulders. It doesnt seem possible that the flatter surfaces could have lost such a mantle and it follows that no such mantle ever existed. Yet the shore lines are here, high above these terrace surfaces.

A big ice floated boulder rests on the slope of one of these terrace surfaces. It is west of the road, in plain sight.

The road climbs over the summit a little south of Evaro. Here the summit is a narrow valley, perhaps structural. No evidence of the lake seen here. the low enough

Arlee is on a broad gravel flat about 30 to 40 feet above the river (Jocko River) which flows northward to join the Flathead. There is no silt on the flat. But the terrace seems to be related to a rock barrier a mile or so north of town, thru which the river has cut a narrow gorge. Perhaps the gravel is post-silt. Perhaps silt underlies it and the stream, let down from the silt fill, has been held up by the rock barrier.

North of this short gorge is a lower flat, approximately the present flood plain. It is margined on the east by a terrace of pale pinkish silt about 30 or 40 feet higher. It is only a remnant of the earlier complete silt floor.

Where the road leaves the railroad, a little north of Ravalli, to climb over into the Rocky Mountain trench at St. Ignatius, is a fine cut in the silt terrace, with the terrace top covered with gravel.

Summit between Jocko Valley and Rocky Mt. trench, east of Ravalli, is 3420 altimeter (A.T.) It is a broad gap with grass-covered rolling hills on which are good shore lines of the lake. Summit saddle and lower slopes have numerous boulders and stream-rolled cobbles. Many have good glacial markings. Apparently they are berg deposits.
Just down the north slope is moraine. The knobs are subdued and the depressions are largely swampy tracts tho two or three, just inside the bison reserve, have shallow ponds. The upper limit is less than 100 feet below the saddle. The ice does not

seem to have reached the summit. Perhaps the abundant boulders in the saddle are actually glacially transported. However, scattered ones up a hundred feet higher, among the shore lines, seem to show that berg ice left a good record above the level reached by the moraine.

This is the Mission moraine, noted by Davis. Its highest altitude here is 3545 A.T. The Mission moraine is a massively broad feature which fills the entire floor of the trench at St. Ignatius and for miles to the north. Its local relief is slight, however, and it is a morainic plain, rather than a ridge or series of ridges. Evidences of the glacial origin of this valley fill are I- till shown in numerous road cuts, 2-boulders strewn over it, some of them huge, all of them of Beltian rocks, 3- glacially smoothed and striated surfaces of a surprisingly large number of these boulders, 4- the morainic sags and swells.

Davis says "dotted with 1000s of blders."

Many sags contains small lakes and swamps. There are no marks of stream erosion. The Mission moraine is subdued, as Davis says, but it was originally so, it has not been "subdued" by the attack of rain and of streams since its deposition.

Does Davis say it is subdued?

Two portions of the moraine may be distinguished, separated by the broad swale now used by Post Creek. Ninepipe Reservoir is a broad flooded tract over the surface of the northern part. The swale between the two portions is surely a sag between two built-up tracts, a record of more rapid retreat than occurred when the two broad ridges of the moraine were deposited.

The moraine topography extends as far north as Crow Creek, I4 or I5 miles north of St. Ignatius. It blends imperceptibly into a plain about Ronan, a plain which has no distinctive features.

The south front of the Mission moraine is at the town. Mission Creek skirts it along its southern edge and crosses a part of it to reach Flathead River. The little patch of moraine ~~seen~~ on the northward slope of the saddle between Ravalli and St. Ignatius is the highest part of the moraine yet seen.

A most puzzling feature of the moraine is the total absence of lake silt on it, while Post Creek sag contains a large fill, making a conspicuous flat abutting rather abruptly against the northern member of the moraine. This flat is cut to a depth of forty feet by the creek. The material is the same pale pinkish silt, varved, containing large boulders of ice-marked Belt rock. Shore lines of Lake Missoula are present on the slopes of the Trench, tho they are faint. They doubtless go up to 4200, certainly thay are away above the moraine surfaces. Yet the silt deposit falls I80 feet short of the top of the northern member of the moraine.

It is quite impossible that here the silt once covered the moraine and has since been eroded off. The surface of the ~~m~~ moraine certainly would receive a silt deposit from the glacial lake which deposited the Post Creek silt if the moraine was there at the time and if the lake covered the moraine.

A few miles north of Ronan is a rolling topography on the surface of the valley fill, very much like the Mission moraine in appearance tho it has very few undrained depressions. But the material is silt, some of which is finely laminated. It is almost as fine as talcum powder and certainly is not a wind-drifted deposit. It looks exactly as should a morainic topography which has been rather evenly buried in silt.

Davis says it is "sparsely strewn with boulders"

Nearer Polson but well south of the big Polson moraine, the elevations are more widely separated and look like sand dunes migrating toward the east. Their material also appears to be of dune sand ~~material~~ texture.

The Polson moraine is a prominent feature, seen several miles away. It is a fine ridge moraine rising perhaps 50 feet above the plain and descending 3 or 4 times as far down its northern slope to Flathead Lake. There are no boulders on its surface, and almost no boulders in its composition. Its material is very largely of stream gravel, in notable contrast with the Mission moraine which has very abundant, very angular boulders.

The Polson moraine crosses the Rocky Mountain trench from side to side, just enclosing the south end of Flathead Lake. Its relation to the lake depression and to the broad plain in front of it is like the situation at the south end of Pend Oreille Lake. But free drainage away from the Flathead Lobe could occur only if the Pend Oreille lobe did not close the mouth of Clark Fork Valley. Not enough yet seen of the Polson moraine to say with certainty that there was no free drainage when this moraine was built.

But see Elmo Moraine, pp 16-17

Polson to Kalispell July I I929

The Rocky Mountain Trench terminates rather abruptly south of St. Ignatius. Northward as far as Kalispell, it is a very strongly marked feature, containing the large Flathead Lake (2900 A.T.) in its lowest part. The east wall is an almost unbroken mountain front north from St. Ignatius to Big Fork near the north end of the lake. This is Mission Range. At Big Fork is a gap, where the Mission Range apparently discontinues and the Swan Range, east of the Mission, comes in to margin the valley. Its front is equally abrupt. Mission Range seems wholly of Belt rocks, dipping eastward away from the trench. This indicates its origin as a fault valley.

The west side of the trench has lower mountains with spurs and lower hills out into the trench. No topographic suggestion for a fault scarp here.

Neither side of the lake shows silt terraces and almost no silt in any cuts. In notable contrast with Kootenay and Okanogan lakes. Yet at the northern end, there is a great silt plain extending from side to side and northward as far as Kalispell at least. Probably much farther. The surface of this plain is perhaps 50 feet on the average above the lake, tho at Big Fork on Swan River debouchure, a good silt section is exposed in a terrace whose summit is about 75 feet above the lake.

The Kalispel silt plain has sags and undrained depressions in it, as tho it mantled a morainic surface. It has also some steep slopes, like ice contact slopes, in it. And there are some steep ice-contact slopes down to the lake level between Big Fork and Creston.

The surface of the plain bears some definite river channels across it.

Tho this silt plain apparently does not all break off in steep slopes at the north end of the lake, it seems to be another profile than that of the lake bottom and to be related to the lake depression as at Kootenay and Okanogan. Instead of the silt surface ~~terminating~~ descending below the lake surface, it seems to terminate up in the air, as tho it once had continued farther at the higher level and had been eroded. But, of course, no complete silt plain at this level ever existed in the valley for

the basin is impossible by any erosion which could remove the silt there and leave it about Kalispel. It seems that we must call for a block of stagnant ice to determine the lake basin at the time the ice was all melted away in the vicinity of Kalispel so that the silt could accumulate there in lake waters.

There are kame piles and morainic hills about the margins of the Kalispel plain. They form a nearly continuous line along the east side. Tho the silt plain abuts against them and in some cases nearly surrounds them, none were found with silt on top of the gravel or till. It seems impossible to explain this by any other conception than that the ponded water, in which the silts were deposited, did not reach much higher on their slopes than the silt now does. If this be correct, then the higher shore lines do not belong to the silt-depositing lake or lakes.

No shore lines seen along the rocky and forested east side of the lake. None on the west side north of Dayton. But the mountain spur along the north side of the bay at this place has a dozen well-marked benches in 300 to 500 feet of vertical. They are about equally marked at all altitudes and come down fairly close to the lake level. The uppermost one, however, is a constructional bench and some kind of Pleistocene deposit mantles the slope here for most of the way down.

Here the note-writing was dropped for a climb up this mountain wall to know from closer observation what was here. Results show clearly the inadvisability of ever depending on long-range observation.

The only shore lines about Dayton Bay are 65 and 180 feet above June high water in the lake. They are cut benches only, are interrupted by valleys and gullies and are none too distinct. But they have flats in places several hundred feet wide, tho the cliffs are low. Above 180 feet above the lake, the regular benches are moraine terraces. Scrutinized more carefully from a distance after the examination in detail, they fail to show a real horizontality. They are irregularly undulatory in a minor way and also depart from level lines in the length of half a mile or so. There are ten or twelve fairly definite features of this sort in a vertical range, by aneroid, of 1300 feet (not 300 to 400 feet). The highest is the best developed. It is 25 to 150 feet wide at the terrace-like top. There is morainic sag and swell topography on this top, three definite ridges in one place occupying it. The highest of these minor ridges is 35 feet above the general summit. Some of the sags are undrained depressions.

This highest moraine bench descends westward a hundred feet in a little less than a mile. Rock knobs on the slope below it bear striae and roundings on the east side and top, but the west edges are plucked into ragged forms. The ice therefore moved westward here up the valley of the bay out of the Rocky Mountain Trench.

The altitude of the highest bench close to the open lake valley is 4200 ft. A.T. Typical till is exposed in numerous nearly bare furrows or shallow gulches.

Drift is found higher than this moraine terrace, both erratics and striated stones being present. But no morainic forms occur above, while for more than a thousand feet below (vertical) the mountain side is marked by weaker but definite morainic benches.

It is curious that these morainic terraces are difficult to see when on them. The best evidence of them is the presence of flats in the re-entrants and minor valleys. These are hardly trenched yet by erosion. The spurs or shoulders do not carry notches, to correspond with the moraine terraces, in anything like the expression found on high shore lines on similar slopes.

Farther around the compound bay, at the head marked by Elmo, this assemblage of moraine terraces assumes the magnitude of a great unit moraine in huge flutings and terracings, some of the terraces carrying kame-like piles 50 to 75 feet high. This lobe pushed two miles or more west of the head of the bay, its crest fully a mile and a half west of the bay and 3550 ft. A.T., 650 feet above the lake. This is about 6 miles farther along the generalized edge of the Flathead lobe, a descent of 650 ft., or about 100 feet to the mile.

The inner slope of this fine crescentic moraine is splendidly marked by a number of subparallel ridges in descending series, doubtless the homologue of the moraine terraces north and east of Dayton. The north horn of the main crest of the crescent is separated from the mountain slopes by a very definite fosse, bare rock walls facing steep moraine slopes. The bottom of the fosse descends eastward toward the lake for the highest part in the midle of the crescent moraine is not as well developed on the horns as are lower members.

See Elmo moraine, Hp 6-7

More of this high moraine banked up on the west walls of Flathead Lake valley shows east of the hiway where it crosses a high saddle between this bay and Polson. Its upper surface is very clearly marked as a terrace which descends southward along the mountain. This hill between hiway and lake must have protruded thru the ice at the time this massive moraine veneer was deposited.

Traced still farther south, this assemblage of morainic terraces and ridges leads out along the southwest corner of the lake to blend with the Polson moraine wh9se summits rise 350 feet above the lake. A large sag occupied by Flathead river. It separates the main Polson moraine from the truly massive southern part o f the terrace-ridge system. This sag must be constructional. It may record a rather narrow extension of the Flathead Lake lobe toward the southwest. If this be correct, then the Polson moraine lying south ~~and west~~ of the lake ~~is~~ and town is but the extension of a moraine from the east side of the valley diagonally across toward the southwest, and is not truly the frontal part of the lobe's great ridged deposit.

A broad flat of very fine, uniform, stratified silt lies along Flathead River in the sag to the southwest of the lake. It is good evidence that the sag is constructional. The surface of this silt is but 75 feet, maximum, above the surface of the lake. Toward the lake, it drops off steeply.

Vicinity of Polson
July 2 1929

Several corrections in yesterdays's notes to be made. The moraine system about Polson is not as simple as first thot.

The Flathead River does not flow thru the sag noted yesterday, it cuts thru the moraine about two miles nearer the middle of the valley. The sag floor rises westward, the moraine terraces banked against the west wall of the valley gradually fade out and the mass of moraine hills that, from Polson, seem to stand out in the valley, become the main moraine. The relief in this part of the moraine, 3 miles west of Polson, is 100 feet and its expression is a confused assemblage of hills and hollows, the hills, in series, constituting rather pronounced ridges oriented nearly north-south The highest altitude secured on the Polson moraine west of tow n is 3300 ft. A.T.

Flathead River first crossed the Polson moraine thru a low place and must have descended 200 feet or so very steeply

down the frontal slope. Cutting into the till, the stream found itself superposed on a buried rock hill and into this it has now cut a short, picturesque gorge about 200ft. deep (maximum). This stretch of rapids is to be the site of a power and irrigation dam. On the north side of the river here is an irregular series of terraces associated with rock ledges over which the stream once spilled. Some of the channel forms in rock suggest scabland. Here, in the cutting of this gorge, is the cause of the definite shorelines 65 and 180 feet above present lake level. There seemed to be one or two minor ones also at Dayton, and these likewise find their explanation here.

But there are no shore lines of Lake Missoula on the Polson moraine as above described. The shore lines are visible on many slopes west of the moraine and, indeed, they come up into the angle between the valley walls and the crescentic moraine. But they are not detectible on its slopes anywhere. The moraine is either contemporaneous with the lake or is younger. In either case, the shores would not exist on the moraine.

Outide of this very strongly marked and very youthful moraine is a great silt plain in the Flathead Valley. The river has trenched deeply into it and on the north, tributary drainage has dissected it into a similitude of badlands. The altitude of the plain is about 2900, essentially the level of Flathead Lake. Yet there could have been no lacustrine connection between Flathead Lake basin and this basin west of the moraine. Probably there was only a narrow gorge in till with perhaps the beginning of cascades over the highest rock ledges. This silt around the south end of the lake reaches at least 75 feet higher.

A mile and a half farther west, in front of the Polson moraine, is a strong ridge reaching southward from the high rock hills to the river. It is very bulky where crossed by the east-west road. It has a high hill in it just ~~west of~~ north of the road, a hill that may be determined by a buried rock elevation. For a mile north of this, it is a curving ridge. Its highest part is at its junction with the rock hills, altitude 3430, or is the mid-length hill whose altitude was not secured. This ridge is a moraine. It ~~seems~~ contains abundant rock that is not local, some fragments striated, and it has at least five shallow undrained depressions on its summit. It is two and a half miles long and quite dissimilar to the other valley spurs of the district. It lacks the freshness and prominence of sag and swell morainic topography of the Polson moraine. It seems clearly to be older.

Drift extends as a thin mantle up to 4000 feet on the rock hills to the north. Above this altitude there is only local rock. The highest shoreline of lake Missoula, altitude about 4200, near the summit of this hill. Not well marked when one is on it but plain enough when seen from below. Many lower strands well marked tho not more so than at Missoula. 16 of them on the old moraine between 3200 and 3600. If it were not for contrast in greeness of grass on the ridges and separating sags, most of these shorelines would be undetected.

Afternoon--- The Polson moraine, south of town, has maximum altitudes of 3380, 500 feet above the lake at its northern base. The vigorous expression found this morning is present here also. No moraine that I recall more closely resembles the Polson than does the Coulee City moraine near Withrow.

The dam site on the river is almost exactly on the line of the outer ridge of this moraine if it were projected across the river ~~to~~ trench.

Much wind-drifted sand mantles the moraine near the railroad and highway crossings.

No continuation of the older moraine was identified on the ~~southeast~~ southeast side of the river. It may be that the descending crest of the older moraine carries it below the till, silt and outwash of the younger on the east of the river. The older feature comes all the way to the river and is there scarped by the river in its present trench. There are several large isolated hills, mostly of rock ~~but~~ but drift-covered, out in the valley south of Pablo Reservoir. One group is elongated nearly east-west and might conceivably represent the course of the moraine.

The feeder ditch for the Pablo Reservoir crosses a broad, low tract in front of the Polson moraine, a tract closed off from the river immediately to the west by the southernmost of the Polson moraine's hills. The canal excavations show a stratified clay or silt on this plain. Altitude is 3200 or more. This is the highest silt yet found, considerably higher than any other. If, as now seems probable, the silt of these valleys of western Montana exists only in the lower places and is not ~~found~~ associated with the higher shorelines, then this high silt is a product of a local lake in front of the moraine, a waterbody which never was a part of the lake farther west where the great plain of silt occurs in front of the Polson moraine.

Lake Missoula shorelines do occur on the south face of the Polson moraine south of the lake. Their development is similar to those elsewhere in the valley, except that the higher levels are not present because the moraine reaches only to 3400. But their existence ~~proves~~ proves that the Polson moraine is either older than, or contemporaneous with, Lake Missoula. It certainly isnt younger. If the Polson moraine is Wisconsin in age, as seems obvious from its strength of development and its freshness, then Lake Missoula is Wisconsin in age. If both the Mission and the Polson glaciations saw a lake Missoula then the lake of the Wisconsin glaciation was at least as deep as the moraine is high.

The high hills rising in midvalley south of the Pablo Reservoir carry the lake shorelines to their summits. 22 shores can be counted on the highest hill and its height above the plain is less than 1000 feet.

Dunes are prominent about three miles south of Pablo, their material typical dune sand. Farther southeast is the tract described a day or so ago as silt-mantled morainic topography. The material in the low hills of this tract is truly a silt and is truly horizontally stratified, so far as excavations showed. Yet it seems very probable that this is a wind-drift silt, representing the dust deposits to the lee of the dune tract. The altitude here is 3000 to 3100, rather high for correlating with the Post Creek silt or the Flathead Valley silt, or the Ravalli silt. And just to the southward and no higher, the till plain of the valley is silt-free.

Another moraine in the Rocky Mountain Trench seems a necessary part of this interpretation. Nine Pipe Reservoir is on a definite morainic topography, with numerous kettles containing swamps and lakelets. Its altitude is about 3000. From this it slopes steeply enough to the south, down to Post Creek, to make the highway grade noticeably steep. Looking south from the Reservoir, or a point a mile south of it, the whole valley floor is well below one. It is this lower tract which Post Creek drains. The creek is 260 feet lower than the reservoir along the highway, and the silt plain along the creek is about 200 feet below. Altitude of the creek at the highway crossing is 2760

South of Post Creek, the surface of the till deposit rises gradually to a maximum of 100 feet above the stream or 50 to 60 feet above the silt plain. This is about a mile south of the creek. Tho morainic, its kettles are much less pronounced and are less numerous than on the Nine Mile Reservoir moraine. This contrast in altitude and in character, and the broad silt-filled sag between, seem to indicate two different moraines.

No silt seen in Mission Creek valley at St. Ignatius. Altitude here is 2940

Summit of the saddle between Ravalli and St. Ignatius is 3160 AT It is essentially the upper limit of the Mission moraine.

The terrace of silt in Jocko River Valley, where the highway begins the climb to this saddle, is covered with gravel. The other ~~terraces~~ silt terraces thence almost to Arlee, lying at the same approximate altitude, all record a river flat eroded in silt, and not the original upper surface of the silt filling. Evidence for this is to be seen in the tributary valley followed by the highway up from Ravalli. Here definite large remnants of the silt occur up to 2830, considerably higher than the terrace top.

A section about three miles south of Ravalli is very interesting. Silt, fine sand, coarse sand, gravel and rubble are here intimately associated, tho the quantity of silt is small. There clearly was vigorous stream action here at times and a definite current most of the time. It seems that this place was very close to the shoreline of ponded water in Jocko Valley. But its altitude is far below the faint strand lines and probably is lower than the highest silt up the trib followed by the hiway out of Ravalli toward St. Ignatius. There is nothing resembling the pebbly or gritty silt of Snake River valley here. Ravalli is A.T. Campbell has a comment on this section in the NPRR guidebook bulletin, I think.

The silt remnants in the gulch northeast of Ravalli ought to be good evidence that there has been no silt deposit much above present silt plains, since completely removed. If silt would remain in this narrow gulch, it would remain on the broad flattish slopes that were submerged in Lake Missoula.

Vicinity of Missoula July 3 1929

There is an extensive silt plain out in Clark Fork Valley west of Missoula and east of the river. Two big meander scars in it, each three or four square miles in area. The silt is at least 80 feet thick. It is pale pink to buff in color, well varved with 20 varves to the foot for one typical measurement. The surface of the plain remnant is dissected by broad drainage swales. The altitude of the summit is 3200.

North of Grass Valley is another dissected terrace remnant of silt, 85 feet above the meander scar at its base. In this there are outcrops of an older gravel resting on bedrock. 24 varves to the foot is a fair average for this silt.

There are terrace fragments at intervals to Nine Mile. Here the silt terrace is 110 feet above the floodplain. Its composition is silty sand, only slightly cohesive when dry. Varving is not shown, tho there is uniform horizontal stratification.

Near Nine-Mile, the river leaves its structural valley and begins its long canyoned course thru the Bitterroots. Notable narrowing, crookedness, slip-off slopes and rock terraces all tell of an erosional, rather than a structural valley. In this valley are the silt terraces but all cuts seen exposed a sandy, rather than silty material. Near Cobden, the terrace top is about 100 feet above the river and only the upper thirty feet or so is silt. Gravel lies beneath. No varved silt seen west of Nine Mile. Instead, the narrow valley contains terraces of gravel within the range of the silt terraces farther up valley. They do not look as old as the silt terraces, however, for they have suffered very little gullying while the silt terrace tops are all rolling with broad drainage trenches. Perhaps the difference in materials will account for this.

Thompson Falls and eastward July 4 1929

The "moraine" that Davis describes here is a very exceptional feature of valley fill and must be seen in more detail. It has numerous enormous blocks of rock in its riverward face and no nearby cliffs or knobs to yield them. It has a rolling topography with minor undrained depressions that look morainic. But it is essentially a great terrace on the north side of the broad valley here. Wind-drifted sand covers most of the top and according to Alden (personal information) the accumulation of this sand in low dunes misled Davis. Perhaps, even probably, there is such mounding on the larger feature but how to get the enofmous boulders moved by the Clark Fork ~~Flathead~~ is a problem. There are no such boulders farther upstream for at least 25 miles, and tho there is a fine mid-valley rock butte a few miles upstream, there are no such boulders associated with it. Nor are there any sheer cliffs at Thompson Falls to yield such fragments. Even if the mountain slopes could have yielded them, they are almost a mile distant from them, out in mid-valley.

Davis calls this the Woodin-Weeksville Narrows.

A picturesque narrow gorge lies upstream from the broad valley at Thompson Falls. Erosional pure and simple; a cut between two structural depressions above and below it.

Splendid gravel terraces upstream from Thompson Falls for several miles, related apparently to downcutting of the rock barrier and "moraine" barrier at Thompson Falls.

North of Plains, a wide structural valley leads north from the ~~ri~~ river valley. Its mouth contains a great terrace of clay or silt, 120 feet high in its scarp. The material is very dense, dark in color, granular in texture and with small pebbles and coarse sand grains in it. It is not at all like the glacial silts, in color, texture or lamination. It has no laminae. (See further work, July 6)

A mile or so east of Plains is the typical glacial silt in terraces 40 feet and more in height, perfectly laminated and well varved, pale buff or pinkish in color.

The nipped spurs, taken by Davis to record glacial erosion in Clark Fork Valley, are very prominent as far up as Perma. There seems no doubt but that the spurs were originally longer and that they have been truncated in some way. Normal stream work might truncate the spurs of its own valley here and there, but could not produce the straightened course from its own originally shoulder-marked valley. Only a vast increase in volume of a stream, sufficient to make the valley a channel, could do this Faulting can hardly be held responsible for the dropped block would necessarily have to fit the width of the valley precisely, the fault trace everywhere lying along the bases of the clipt spurs. And there is no other conceivable explanation, except that of Davis.

Yes, there is. See Dec 1932

Another feature of the valley where the truncated spurs exist is the multitude of rugged rock knobs and hills that lie a little inside the valley walls. Some are not far from central in position tho most of them are close to the clipt spurs. They seem very much like the irregular rock knobs in glaciated valleys in northern Washington and southern British Columbia. They dont agree with the stream erosion hypothesis or the faulting hypothesis. They do not occur above the gorge-like valley below Perma. No ice-rubbed surfaces were seen on any of them.

But the most interesting and most puzzling forms seen between Plains and Perma are the high-level fills in the larger steep-grade gulches. At least a dozen well marked ones are shown on the north side of the valley. They are thot by Pardee to be deltas built in Lake Missoula. ~~Campbell accepts this explanation but~~ Davis calls them lateral moraines of his ice tongue.

One of these was examined in detail. It lies just back of the round-house at Paradise. It is a broad fill, the summit 1200 feet wide and nearly as long along the gulch length. This summit is nearly flat but is 40 feet above the contact with valley walls. From the summit, the slope down the gulch is very steep, about as steep as the debris will lie. It is all grassed, however, no sliding places and no washes interrupting the slope. This steeply sloping front descends essentially to the valley floor, becoming narrower and more gently sloping in the terminal part until it is a rather inconspicuous fill. Upgulch from the summit, the surface drops off abruptly to a closed depression containing a pond 100 feet across. The pond surface is 80 feet below the broad summit but since the deposit is lower on the valley sides, the closed depression is only 40 feet deep.

The deposit is ~~clayey~~ composed of local rock; diorite and the Belt sedimentaries. No foreign fragments were found. Some of the pebbles and cobbles are rounded but most of the material is angular to subangular. A great deal of bouldery material is present, even out on the summit. The summit is 800 feet above the valley floor. Campbell says "at least 400 feet".

Farther upstream, the ~~da~~ enclosed flat rises into a bubbly fill that occupies the bottom of the gulch. It is higher in the middle in places and looks like a steep alluvial cone in the gulch.

Three other such forms like it within the next three miles downstream. Two of them occur at about the same altitude. One is hardly more than half as high. Two have been trenched and one has a gully down its front. One has a definite slope of its crest along the valley, descending upstream.

Others above Paradise as far as Perma, on both sides of the valley, generally about 800 feet above the river, but in a general way lower with increasing distance upstream. It is not known if they have depressions back of them.

If I found one of these features along the scabland channel routes I would call it a bar. Yet they are not composed of stream gravel and are far higher up on the valley slopes than any bar known. That ~~they~~ one examined is not a delta is clear. That these little gulches could have such prominent deltas in a lake whose shorelines are so weak as are Missoula's seems impossible. That only these little gulches should preserve deltas seems also impossible. Are they lateral moraines? Their forms are not hummocky or moraine-terraced. (nor do they carry L. Missoula shorelines) Yet they are limited to that part of the valley which possesses the clipt spurs. Whatever they are, they are not typical of any recognized land forms.

But this was not shown

Evaro pass is 3958, 750 ft. above the upper limit of silt in the plain at Missoula. Isn't it impossible to bring any silt thru this pass without leaving it on the intermediate slopes between the pass & the siltplain? Only by a slowly subsiding lake could it have been removed from these slopes.

Possibility of silt from local glaciers in Bitterroots & Cabinets to be considered.

The Lake Missoula silts are 150 feet thick at Dixon. They are typical of other silt sections thus far seen, except those 3 miles south of Ravalli. Much fine sand in which there is very little cohesion and doubtful varving. If varved, the individual layers are one to three inches thick. The altitude of the top of the silt deposit at Dixon is 2650 ft. A.T. The silt scarps and terrace flats are very conspicuous about this place. As a broad valley fill, the silt deposit extends up the Flathead for several miles. It is now much dissected. It is probably continuous with the silt plain west of the older moraine west of Polson, alt. 2900, tho if so the surface of the silt rises in that direction 250 feet in about 20 miles.

But this was not shown.

If there is a continuous silt plain here, then the water level (if there has been no warping since deposition) necessary to account for the silt plain west of Polson was 250 feet above the silt plane at Dixon. The hypothesis which seeks to account for the absence of silt on all valley slopes of the region above the valley bottom silt plain by the conception of silt surface marking the water surface (the lake silting full) fails here. It fails also for the 3200 foot silt plain north of Missoula unless that was a local lake dammed by Davis's Thompson Falls ice tongue. This stretch of 20 miles along the Flathead should be seen. If the hypothesis fails, then the silt of the these valleys may well be Lake Missoula silt, tho why it does not occur on the gravel flats and gentle slopes between the valley floors and the higher shore lines is unexplained.

Charlo is on the Post Creek moraine. A section in till 60 feet thick shows along lower Post Creek at Nine Mile where the railroad follows the creek for a short distance. This till weathers into hoodoo forms exactly like the till at Flathead Falls west of Polson. Its color is the same, as is its content of rolled cobbles and pebbles. It has a reddened upper zone three or four feet thick, tho the color is faint. This till goes under the silt plain to the west at about 2640. This upper limit of silt agrees closely with that just east of Dixon (2650). The slope of the moraine here is very smooth and even. It is a definite descent to the west as well as to Post Creek and Mission Creek to the south. Undrained depressions are not uncommon. But why there should be no silt on the moraine higher than 2650 (about) when it is 2900 a few miles west of Polson is a puzzle.

Why is there no silt along Clark Fork west of Plains? Especially in the broad valley about Thompson Falls, there should be silt. Why is there none is the vicinity of St. Regis? How did the silt in the terraces north of Missoula get there? ? Only by remaining in suspension in a lake and a lake that had but two narrow connections, Evaro and the back-habided St. Regis turn, with the water that was in open connection with the Flathead icelobe.

If Davis is right about glaciation at Thompson Falls and upstream to Perma, might not this bring ice sufficiently near to the Missoula district to explain the puzzle? Yet, even so, the St. Regis region without silt is between. Only by removing the silt in the narrow valley about St. Regis by subsequent stream erosion can the absence of this deposit be explained.

To prove Davis right, till and glaciated surfaces must be found in Clark Fork Valley between Thompson Falls and Perma.

A better hypothesis would be that Davis' ice tongue at Paradise & Perma & back up the right-glacial trough toward St. Regis caused the local pond for the 3200 Missoula silt. There is no other silt as high except a small patch on the moraine-filled Hayhead Valley north of Pablo Reservoir.

In support of this hypothesis is the absence of glacial silt up the Bitterroot Valley south of the Polo narrows. All ridges above the present meander belt and flood plain are 3187 & higher. The silt-depositing lake never reached this far south, tho the shoreline-forming lake was there & the valley had ample opportunity otherwise to receive silt.

But such a lake, never rising much above 3200, yet silting full (or essentially so), must have an outlet to maintain its constant & long-continued level. The only outlet possible would be across or along the edge of the ice dam. This ~~for silt~~ is not a very satisfactory solution. And a further objection is that silt contributed by the Cordilleran tongue obstructing the dam would be carried away thru the outlet & would not get 60 or 70 miles up the narrow lake. Silt thus must be gotten from local glacier in the Bitterroot & cabinets tapping Eocenics buried in the silt then must be limited to Cabinets / Bitterroot rocks

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Let us conceive that the Pend Oreille ice dam gave way after the shorelines were formed but that the Columbia west of Grand Coulee was still blocked. The scabland torrents then would originate but the lake would lower only to 2550 (about), the altitude of the channel heads. If the gravel floor south of Lake Pend Oreille, or some combination of ice still in the valley south of Lake Pend Oreille ~~and with~~ rock shoulders or moraine or gravel, kept the level upstream in Clark Fork Valley (Lake Pend Oreille and upstream) higher than 2500. then the lake would lower only from 4200 ~~to 2550~~ to some figure above 2550 This might be conceivably high enough to cover the 2900 silt west of Polson, the 2800 silt of Post Creek and the 3200 silt of the Missoula district. The conditions during this hypothetical lower stage, and the duration of that stage, might then explain the absence of silt higher than the flats noted Yet, unless there has been tilting, these silt deposits should all be the same or at least the southern ones should be no higher. For if silt was deposited to 3200 near Missoula, far from the edge of the ice, it should be as high near the Polson moraine.

The National Bison Range is an almost isolated hill group in the Y at the south end of the Rocky Mountain Trench. One arm reaches to St. Ignatius, the other to Dixon. It is an inverted Y. The highway crosses the low saddle between these hills and the mountains east of Ravalli and Arlee. The hill group is marked on all sides, even in the saddle, by Missoula shorelines.

Plains to Elmo July 6 1929

A large lobe of glacial ice has occupied the valley of Lynch Creek which mouths into Clark Fork just west of this town. The evidence is in the splendid morainic topography that lies on the divide between Lynch Creek and Boyer Creek to the east and about three miles north of Clark Fork valley. The moraine lies well up on the east wall of Lynch Creek valley and is easily seen, tho not clearly identified, from the valley floor main road. Near the top, it is a large moraine terrace with several depressions between it and the rocky ridge crest. One short kame-like sharp ridge. A little farther north, it crowds completely over the crest into Boyer Creek valley. Here it has strong development into kame and kettle topography. The altitude of the moraine bench on the east wall of Lynch Creek valley is 3500.

Over in Boyer Creek, the hiway follows the edge and climbs up along the slope of a singular deposit associated with this moraine. It is composed of cobbles and boulders entirely. Its steep eastern face is a veritable talus slope, largely barren of vegetation. Its top is flat and not far from level, standing at about 3500. This flat has shallow kettles in it. The whole feature is elongate along the east face of the moraine topping the divide and is in strong contrast, as a constructional feature, with the opposite (east) wall of Boyer which is typically furrowed into minor drainage ways of a well-developed valley. The flat seems to be an outwash feature, a kind of pitted plain. The sub-rounding of many of the fragments seems to point to the same conclusion. But it seems much more like a delta than any other form that outwash could take in this situation.

Dog or Rainbow Lake is clearly dammed by moraine at the west. That this moraine came from the same ice as that on the Boyer-Lynch divide is clear for the characteristic topography is traversed all the way (about 4 miles) between. The morainic ridges lie up against the south wall, enclosing swamps and lakelets. Ice seems to have been as far as the east end of the lake for here the surface between lake and rock wall to the south is highest out away from the walls and it slopes down decidedly toward the talus from the cliffs.

No notable range in character of debris was seen in any of this moraine. Most of it is composed of pale greenish to grayish fine-grained quartzite and argillite. Diorite is also present. Indeed, diorite knobs project thru the moraine on the summit of the Boyer-Lynch divide. But none of the Siyeh limestone, none of the red saccharoidal quartzite cobbles, none of the bright green and bright maroon argillites that are so common in the Flathead Valley drift. The material is but little worn, almost all is sharply angular or very slightly subangular. No striae found on any fragments.

There are three possibilities for the source of this ice. All allow the distribution in altitude noted. I- A lobe of Cordilleran ice crossed the relatively low divide at the head of Lynch Creek. 2- A local glacier developed in the headwaters of Lynch Creek. 3- Davis's Clark Fork glacial tongue pushed back up Lynch Creek.

The first explanation seems altogether the most probable tho there should be a greater variety of debris by this hypothesis, unless the basal debris from the north was trapped back of the Lynch Creek divide and only the upper, cleaner ice came across and got its material locally.

The second explanation is impossible for it requires glaciation of large volume at lower altitudes than any glaciation whatever is known to have occurred elsewhere in this part of Montana.

The third explanation needs to be looked into rather carefully before it is discarded. But more field examination must be made first.

Silt in Lynch Creek valley is 170 feet thick and its upper surface is 2660 A.T. Much of it is fine sand but there are thick members of varved clay of exceedingly fine grain. If the right moisture content is present, it can be shaved as thin as paper. This silt terrace is the same one which yielded the tough, dense, pebbly clay, from another cut, a few days ago. Except for the unusual character of the first sample taken, this large thick terrace is typical of the glacial lake silts in this region.

A large structural valley extends northward from Perma on the Flathead as far as Niarada. It is narrowed and interrupted by hills and spurs of bedrock near Niarada and is completely severed between Camas Prairie and Hot Springs by a small, narrow range of hills whose lowest pass (Markle Pass) is about 400 feet above the flat floor of the valley to the north.

The southern half of this valley (or the southern valley of these two) is known as Camas Prairie. Its lowest part, at the south end, is only three or four miles from the Flathead and is not much more than 200 feet higher, if it is that much. The floor rises toward the east side and the north end. Exposures show stratified gravel. Plenty of boulders lie on the surface, some of them striated.

The rising floor of this plain of washed gravel terminates at the north, close to the transverse range of hills, against a splendid group of moraine terraces of ridges lying along the ~~outhe~~ southern slope of the hills. From the south, it looks as tho a glacial lobe had pushed northward against this transverse ridge but when the pass is crossed, it is at once clear that the ice came from the north and pushed just across the hills and down to the north end of Camas Prairie. In other words, the highest of the moraine terraces are the youngest, not the oldest. See further description July 7

Silt from the Perma terraces extends part way up the creek toward Camas Prairie but none was seen on the Prairie.

Markle Pass is a bit of real scabland with ragged bare buttes separated by rather deep rock basins. These features are limited to the pass alone; there is no channel form down across the moraine terraces of ridges. Glacial water evidently spilled southward across this pass but it must have entered standing water on Camas Prairie a little below the Pass and above the moraine terraces. There should be a deltaic deposit recognizable here. Must see it again.

The larger portion of the structural valley lies north of the Markle Pass range of hills. It is drained by ~~a rather narrow valley thru the east wall~~ Little Bitterooot River which escapes by a rather narrow valley thru the east wall of the structural depression not more than five miles north of Markle Pass.

Glacial silt, with some very fine sand, covers a great area here, extending from the north foot of the Markle Pass hills to Niarada, a distance of I7 miles direct. The surface of this silt plain is ~~ab~~ about 2775. It is much dissected by shallow valleys. The Little Bitterroot has cut about 50 feet deep into it.

This silt must be younger than the Markle Pass moraine for it ~~cov~~ covers the area occupied by ice when the moraine was built. The moraine, being the southernmost of all morainic topography here, ~~must~~ probably is correlative with that in Lynch Creek-Boyer Creek divide and with the Mission Moraine at St. Ignatius. See later note July 7

(Another bit of the Markle Pass moraine occupies the pass ~~I and~~ one and a fourth miles farther west, used by the road between Plains and the Little Bitteroot Valley. This pass, 3386 A.T., is about I00 feet higher than Markle which measured 3276 A.T. It contains two good-sized ponds almost on the summit and morainic forms and debris lie a thousand feet of so farther south than the pass itself.)

Traverse made from Niarada north to Glacier Park Hiway in search of younger moraines than ~~that~~ at Markle Pass. Only scattered glacial debris was seen in a few places, particularly on hills of volcanic agglomerate north of Niarada (Sullivan Hill). The Wisconsin moraine is encountered abruptly at the Dude Ranch a quarter of a miles south of the Glacier Park Trail. It is not marked here but about two or three miles west, it has a strong frontal slope, with a great fosse between it and the mountains to the south. The map show McGregor Lake in this fosse, and indeed, a long line of lakes and meadows ~~ows~~ and marshes mark the frontal drainage of the Wisconsin ice for thirty miles or so. This long marginal valley, or assemblage of valleys, is drained northward by Fisher River at the western end, southward by the big Thompson in its middle portion and southward by the Little Bitterroot toward the east. The Little Bitterroot goes thru a short, very marked gorge about two miles south of the Dude Ranch. The road climbs considerably south of the Ranch to parallel the impassable (?) gorge. Here is a clear case of Wisconsin derangement of drainage, the ponded waters in the marginal valley rising until they overflowed a pre-existing divide here.

No signs of a moraine found between the Dude Ranch and Markle Pass.

Lake Missoula shore lines up to the top of Sullivan Hill's highest summit, north of Niarada, are as well marked (or as indistinctly marked) as those on Mt. Jumbo at Missoula. This is far from a check bench mark but these shore lines very probably go as high as 3800 here (later reading, better checked from Flathead Lake, make the highest 3730). No shorelines were seen farther north, chiefly because of the forest cover and because the small size of bays probably did not afford opportunity for wave development. The Sullivan Hill shores are the most northern records of Lake Missoula yet known.

Looking east from the summit of Sullivan Hill, across the dissected silt plain in the foreground, one sees a flat-bottomed valley without a stream, bounded by steep, mountainous walls, leading eastward toward Flathead Lake. It is called Big Draw on the Forest Service map and is indubitably a former main stream course between Flathead Valley and Sullivan Gulch. Which way it flowed is not yet clear.

Stone calls it a former course of the Flathead River.

A traverse of this valley east to Elmo on Flathead Lake shows a surprising thing. The valley floor, which looked so flat from the hill summit and seemed so clearly to be a silt plain, is a valley train of cobbles and boulders. It leads west from the big Elmo moraine in section 22, descending 340 feet in 9 miles. In section 26 of the next township west, two wells have been dug for 80 feet in the gravel fill without penetrating thru it.

The Elmo moraine is a very impressive thing, seen from the west and also from the summit. Its western slope is very steep, its crest being close to the west edge. Across its summmit, a little south of the middle of the valley, is a definite stream-cut notch produced by discharge for a time from the bay arm of the lake after the ice had withdrawn from the moraine. The floor of this channel has several terraces and stream-cut bluffs, showing some lowering during its occupancy. Altitude here must be a little higher, however, than across the rock sill in the Polson moraine, else the Flathead today would occupy the Big Draw.

The floor of the channel thru the moraine is marked by some deep kettle holes, the deepest being 110 feet below the adjacent terraces. There must have been iceblocks buried here that did not melt until after the discharge thru the notch ceased.

The most significant feature observed here, however, is the relationship between Missoula shorelines and the moraine. These shores just west of the moraine and lower than the higher parts of the moraine are as definite as anywhere on the Big Draw slopes. They are also definite above the moraine at each end and actually can be seen well to the east along the north side of Big Draw, two miles back along the northern horn of the crescentic moraine but above the scarps of rock which face the moraine.

But there are no shorelines on the moraine! They can be traced right up against it, where they end. Lake Missoula was earlier than the Elmo moraine and there was no lake stage in Big Draw after the Elmo moraine was built.

Elmo to Plains July 7 1929

Re-examination of the Elmo moraine (which is like the Polson in being composed largely of a very pebbly till, pebbles rounded) shows the possibility of there being two very faint shorelines for a short distance along its western front. But the numerous shoulders, some of them close against the south side of the valley, are completely innocent of shore line notching tho hardly a hundred feet away, the hillside on which the moraine terminates has good shore lines.

The fosse on the north side of the Elmo moraine looks from the ~~we~~ west like a drainage valley emerging toward Big Draw.

The floor of the trench thru the moraine descends with almost no change in gradient out onto the valley train. Total descent for 9 miles is 340 feet, or 38 +/ plus feet per mile. The gradient fo the first mile is about 40 feet; this is all in the moraine.

The valley train gravel disappears where Big Draw crosses the 50' latitude line. Tho the flat continues down Sullivan Gulch, no gravel is in sight. But it seems that it must be present, buried under alluvial deposits of the reworked silt, for the valley thru the silt continues and grows deeper, the gradient of the valley train does not notably decrease at the place where the gravel disappears and the valley train gravel is so coarse at the lower end of its visible length. Terraces of silt 25 feet high overlook the lower end of the valley train.

The valley train is younger therefore than the silt plain, younger even than the dissection of the silt plain. The moraine and the valley train are of the same age. The moraine is younger than the shore lines. Are the shorelines and the silt of the same age?

The silt plain a mile or so north of Niarada is 2900 ~~feet~~. This agrees with the silt plain west of Polson and is about the northernmost of silt in this part of Montana.

Elmo moraine summit 3486 A.T.
" " upper terrace 3346 A.T.
" " trench floor 3306 A.T.
" " kettle hole in upper terrace 3236 A.T.
" " valley train head 3266 A.T.

All these altitudes below 4200. No lake therefore when Elmo moraine ~~was built~~ + its V.T. were built. ∴ No Wisc. dam for L. Missoula at ~~that~~ time.

The moraine summit therefore is 220 feet higher than the valley train head and 600 feet above Flathead Lake. These figures are approximate only. They may be forty feet off but the relations among them are correct.

~~-h4-no56h45n-4nr~~ Shore lines of Lake Missoula on the northern end of the hill range between Camas Prairie and the lower ~~end~~ part of the Little Bitterroot is beautifully marked on the morainic material tho the hard rock slopes do not carry the marks. The markings show best back in the minor gulches which have been partially filled with moraine plastered against the mountain side.

Moraine embankments here shows the shorelines, hence are older.

The most interesting feature of the mountain sides here is the presence of fills high up on the slopes, back in the gulches, which look very much like the "deltas" along Clark Fork between Perma and Plains. One of these was climbed in the hope of finding a morainic depression back of its crest, similar to the depression back of the summit of the one at Paradise. This "delta" is 790 feet above the Little Bitterroot. Its face is scored with Lake Missoula shorelines to the summit. Back of it is a deep gulch developed since the morainic material was deposited here. But the gulch has only ~~sli~~ g slightly modified the original back slope which possesses good remnants of two depressions. The tributaries now descending to the gulch back of this bit of lateral moraine are headed to continue thru where the moraine lies. Instead, they turn abruptly and leave by way of the gulch which is much more ravine-like than they are and not

one fifth as wide at the level of the lateral moraine ridge as the older course now blocked by the moraine deposit.

Certainly this is a lateral moraine deposit, as are a dozen other on this north-facing group of hills. Certainly there is ample reason for accepting this explanation. It seems highly probable that the Perma-to-Plains features are genetically identical and that Davis will be vindicated by the discovery of more evidence for glaciation in Clark Fork valley about Thompson Falls in a few more days of field work.

The moraine down the south slope of the Markle Pass hill range is not the terminal. There are excellent moraine hills and kettles on the pass ~~flood~~ followed by the road up Big Gulch and over into Camas Prairie from the east. The altitude here must be as high as that at Markle Pass. Below this pass, Camas Prairie structural valley has a fairly steeply sloping plain westward to the north-south median line of the valley. This plain is diversified by moraine ridges and parallel sags of remarkable regularity. The ensemble looks, from the pass 300 feet or so higher, like gigantic ripplemarks The ridges are from 10 to 20 feet high above the separating sags and are littered with erratic boulders Some sags are wholly undrained, others have portions that are closed depressions. Most of the sags have been used by running water and modified into stream furrows.

~~Glacie~~

Glacial ice clearly reached as far south as Camas Prairie store, six miles south of Markle Pass. The ridges are much gentler here, however, and appear to die out to the southward. There may have been no terminal moraine building habit for the early glaciation; witness Mission Moraine and Lynch Creek moraine. On the other hand, the marked ridges and accumulations south of Markle Pass may be a later moraine. A later one is needed if the Post Creek (Nine Mile Reservoir) moraine is to be established.

An hour later, traverse was made of the low hill barrier between Camas Prairie and the Flathead, now trenched by Camas Prairie Creek. It is three miles or so across, 500 to 800 feet above the Flathead and only a h hundred feet or so above the flat western part of Camas Prairie. The rock floor of Camas Creek has held up Camas Creek from trenching back in the prairie.

Since the flat is a Pleistocene fill in a structural valley and its drainage now just spills over a but slightly trenched sill, it is interesting to consider the location of the preglacial discharge. This could hardly have been the present route, yet it must have been somewhere at the south end of the valley.

The traverse shows abundant glacial drift over the hills of this barrier. In places it appears that a glacial till is beneath the surface. Many clearly striated and bruised fragments occur. Siyeh limestone, maroon argillite, green argillite, red saccharoidal quartzite; all these are characteristic of the drift in Camas Prairie and the Little Bitterroot valley to the north. Boulders several feet in diameter are present, as well as many smaller pieces. Even a morainic sag containing a good-sized pond, and several minor sags

were found. This drift continues to within less than a mile of Flathead river where bedrock becomes prominent. Yet the drift may continue clear over the tops of the bluffs facing the river. They were not examined sufficiently to be sure. At any rate, the Camas Prairie lobe came within less than a mile of the Flathead, much farther south than was thought a few days ago. Campbell?

Just north of Perma is one of the "delta" features which Pardee first noted. It lies in a re-entrant in the face of the bluff, a re-entrant which may be the junction of two minor rock-cut gullies. The crest is near the frontal edge, 3015 ft. A.T. and 460 feet above Perma station. It is an elongated oval in outline, 1200 feet long and 600 feet wide, the length at right angles to the river valley. Its summit area is entirely surrounded by lower surfaces, 25 feet minimum and 100 feet maximum below the top area. Two undrained depressions back of it, the deepest (100 ft. below the summit) having a closed depression 60 feet deep. The summit has a shallow saucer-like depression. The north end of the form is elongate like the tail of a drumlin and the south end has a convex vertical profile but a concave horizontal one. Surrounding rock walls rise 50 to 100 feet above the summit on the west , north and east.

This constructional form is composed dominantly of the local slabby argillite but there are erratics of every kind found in Camas Valley except Siyeh limestone. There are no erosional forms of any sort on the pile.

This is no more a delta than is the one back of Paradise round-house. There are, all told, 22 of these curious deposits in ~~sight~~ sight from the road along the south side of the Flathead between Perma and Plains, and 6 on the south side. There probably are ~~m~~ more on the south side but the location of the road and the presence of a forest cover makes it impossible to see them all. They lie at all altitudes, they are of different magnitudes, they vary in the character of their crest line as seen from below, some sloping down to the east, some to the west, some lowest in the middle, some highest there. Because of trenching of some of these, it can be seen from below that three of them that were not climbed once had depressions back of them.

The largest of all lies in the mouth or on the east side of the mouth of Boyer Creek valley. And Boyer Creek has numerous mounding and terracings, modified by erosion, below the moraine limits noted two days ago. It seems now that Boyer Creek Valley has older moraine in its lower three or four miles, in front of the moraine that crosses the divide from Lynch Creek. It seems clear that glacial ice has entered the Flathead Valley here as it probably did at Perma.

The "deltas" are lateral moraine deposits made by glacial ice in Flathead (and Clark Fork) Valley They agree with the truncated spurs here and farther down toward Thompson Falls. Davis is right, Pardee and Campbell are wrong . Hanging valleys, remarkably well shown, are associated with the truncated spurs between Plains and Thompson Falls. They are all relatively small affairs, any hanging condition of larger ones apparently having been destroyed by subsequent stream work.

These features of "deltas", hanging valleys , scarped and truncated spurs and ragged rock hills, partly out in the valley at the base of the truncated spurs continue a few miles below Thompson Falls. A much wider structural valley is entered ~~a few miles~~ above Belknap and from here almost to Noxon none of these features were seen. ~~This~~

This part of the Clark Fork valley contains a high gravel terrace, Campbell noting that in one place it is 320 feet above the river. It seems to be a continuation of the high gravel terrace remnant east of Thompson Falls tho there are the altitude above the river is about 100 feet. The river is in a deep trench in most places thru this terrace,

a trench either in gravel or in bedrock or in both.

This terrace continues down the valley far below Noxon. In some places it carries a few feet of silt. It seems to be replaced by thick silt farther northwest. But the genesis of the gravel flat isnt at all clear.

The Thompson Falls debris fill seems clearly to be a moraine made by a tongue of ice in Clark Fork valley. Its easternmost member, about two miles east of town, is nearly separate from that back of the town and is essentially an elongate ridge about a mile long, standing 70 feet above a low tract between it and the cliffs and more than 400 feet above the river. Its highest part is made of knobs of rock, it carries no undrained depressions and no striated fragments were found on it. The only exposure showed very coarse, very poorly assorted gravel, rather than till. But it can only be a constructional form, and only a moraine, if constructional. On its riverward lower flank is some minor dune sand topography superposed on it.

Campbell's speaks of a lobe of the Cordilleran ice up the Clark Fork valley as far as Noxon being joined by another tongue down thru the Cabinets by way of Bull River. He cites erratics 2000 feet above the stream and glaciated surfaces of the bedrock. None of this was seen but scarped spurs and hanging valleys are present from Noxon on downstream to attest the glaciated condition of this part of the valley. Yet Alden, last summer, said that neither Spokane nor Wisconsin ice moved more than a few miles up Clark Fork from Lake Pend Oreille. Was all of this tongue from Bull River?

If I were still looking for side-hill gashes, I surely would find enough of them in these glaciated portions of Flathead and Clark Fork valleys. A phase of glacial undercutting of glacial oversteepening seems to be the plucking of a gorge across a spur and the leaving of portions of the spur as ragged buttes. One particularly marked feature of this kind is along the highway a few miles south of Clark Fk. village.

Outlet of Glacial Lake Missoula July 9 1929

All day was spent on the divide along the entire western wall of Johnson Creek in the vicinity of the spillway which (Pardee and?) Davis point (s) out as the probably high-level outlet of Lake Missoula.

Aneroid error at the start was about 50 feet. On return, the error was 15 feet. The day was fair and it seems probable that no great changes took place between morning and evening.

Trusting the aneroid, there is no 4200 foot notch along this divide between Johnson and Granite creeks. The lowest notch found read 4800 on the dial and the one mapped as 4200 read 5000. Obviously the mapping was done with very little traverse work. No blame can be attached for the mountains here are very steep and the vegetation very difficult to get thru when off a brushed-out trail.

There is no sign whatever in any of the four or five saddles examined of a glacial river having ever used them. All are rounded ridge summits and no more. No bare rock, no cliffs bounding them, no terracing in them, no boulders, no deltaic accumulations or channel forms down the hillside to the west.

Lake Missoula never discharged across these mountains.

(the northernmost Lake Missoula shorelines seen in this study are on the east side of the valley at Cabinet)

The highest foreign material seen in Johnson Creek valley was a large rounded granite boulder at about 3550 aneroid.

Sand Point to Rockford July IO I929

A gravel pit two miles west of Sand Point along the Newport hiway shows excellent delta structure, with foresets diping west and southwest, and with three feet of topsets on them. The exposure is in a hill that is semi-isolated now, the delta being at the extreme south tip. Looks as tho there had been much erosion here since delta-building, or that the delta was built directly from the edge of the ice. The lake surface then was probably held up by the moraine at Albany. Delta top not measured but at least 50 to 75 feet above the present lake level.

Bayview, on the south end of Lake Pend Oreille, is shut in on the drift plain side by a steep descent in till or gravel. Looks like an ice-contact slope. The ice apparently built up a great waste fill in front of it. There is little more in the way of moraine ridging south of Bayview than south of Granite. One passes from the moraine to the outwash almost without any descent. The general altitude of the outwash plain east of Athol is 2400. Along the east side, adjacent to the mountains, is a gravel terrace 90 feet higher. A gravel pit shows fully 8 feet of dark stained gravel above the bright material. It is not decayed nor strongly red in color but is distinctl y dark reddish brown for that depth. There is no dust cover on it, at least near the edge of the terrace where the pit is located. This gravel should be Spokane in age.

A prominent bench of Columbia River basalt east of Ramsey lies against the mountains of deformed sedimentaries, and its basalt unconformably overlies the argillite, with a weathered zone of prebasalt mantle rock between. Top of the bench is 270 feet above the base and carries faint morainic topography and plenty of erratic boulders. This should be Spokane till.

The same kind of morainic expression and abundant erratic boulder distribution is to be found over the southern extension of this basalt bench, west of the north end of Hayden Lake. It seems to descend gradually and to blend into the gravel plain which dams the lake. This must be seen again and if it is Spokane gravel which makes all these lakes along Rathdrum Prairie, the fact must be clearly established.

The spur of the Mica Peak group of mountains which lies between Spokane River and Cougar Creek clearly has glacial erratics on it and seems to have faint morainic ridges and hollows among the small rock hills of its northern slope, up to 2500 at least. Anderson insists that Spokane ice was up here. If so, it had to melt back considerably before the great flood of glacial waters arrived, for there are no adequate glacial waterways, if any at all, along this slope.

The divide at 2810 crossed southward. In Cougar Creek, just below the road crossing of the divide, are dozens of erratic boulders cobbles and pebbles, several of them striated very definitely. Two boulders of the granodiorite porphyry are here. The highest erratics found are 2640, altitude checked from the 2810 pass. There are but few of them farther down the valley.

Along Temporary 95 hiway, which leads southward thru Mica and near Bellgrove, another large collection of foreign boulders, cobbles and pebbles occurs at a little less than 2500 on the south slope of Cougar Creek valley. The Mica upland, which is a bench of Columbia River Basalt, carries numbers of such boulders. Indeed, they were found all along the road beyond the south edge of the Rathdrum sheet, all of which along the highway is below 2600.

Several places seen along this hiway where old stained quartzite gravel is sliding down the face of the road cuts. This gravel must predate the erosion of Couer DAlene valley.

Less than a mile above Rockford, along a tributary of Rock Creek, probably Mica Creek, are several foreign boulders and cobbles, one cobble definitely striated. The soil where they occur is a pebbly silt, identical with the pebbly silt of all scabland backwaters. The altitude here is 2406.

Do the pebbly silts occur in Coeur D'Alene Lake valley, along with the erratic boulders? See July 20 p.34

Rockford has a U.S.G.S. bench mark near the station. It is 2376

Mica to Post Falls July II 1929

The valley of California Creek at and above Mica was examined for glacial silts but none can be identified. There is too much arkosic debris from the granite hills to make it possible, apparently, to use the variety of pebbles criterion. Essentially no basalt farther north makes it unlikely that the feature of tiny basalt particles could be present. None were seen, at any rate. No stratification in the superficial mantle rock.

The eastern of the two passes across the higher ridge two miles or two and a half miles north of Mica contains a deltaic or fan-like gravel deposit a little below and south of the summit. Dipping beds descend southward. Gravel is almost wholly of granitic debris very poorly worn and poorly sorted. Large boulders of kaolinized and crumbling granite, even boulders of residual clay, occur in the gravel. A few foreign rock fragments present, their outlines and their hard exteriors in contrast with the angularity and crumbling condition of the local material. Altitude of the pass is 2400. Its floor, a little north of the pit, bears a number of mounds, IO to 30 feet high, that are elongate with the pass and have a few closed depressions among them. Either morainic or bar accumulations.

Not Mica?

The mouth of the creek valley down the north slope from this pass is closed by a broad barrier of gravel 60 feet above the marshy flat. The altitude of the flat is 2040. The barrier is marked by three great broad low ridges, the relief between sags and ridges being about 50 feet. This barrier of gravel is all of three miles wide. Its northern slope is about I00 feet high above a gravel flat into which the river has trenched about 40 feet. The northern slope is steeper than any other slopes in the great gravel compound ridge and is strewn with thousands of boulders, many of them four feet in max. diameter, almost all of them larger than elsewhere in the deposit. This northern slope looks as tho a great stream had eroded it, as tho it were not an original constructional slope. It may be thot of thought of as the descent from the Spokane gravel to the Wisconsin valley train. This idea involves several consequences that will be outlined shortly.

The mouth of Saltese Creek valley is partially blocked in a similar fashion, the drainage escaping far over to the west side of the valley, hard against the rocky point projecting out into Spokane Valley. In each case, the highest of the barrier is to the east.

Liberty Lake valley is also similarly blocked, the surface of the barrier being 2I50, at least I00 feet above present surface of the lak This barrier, like the others, slopes rather steeply down to the enclosed or partially enclosed basin in the trib. valley mouth. It is also diversified by very broad, gently sloping ridges on its summit, ridges that can only be contructional. The summit is II0 feet above what is here called the Wisconsin valley train, the wide flat of gravel along the river.

Above Spokane Bridge, the river is close to the rock slopes along the south side of Spokane Valley. The broad flat in the middle of the valley continues northeastward, when traced upgrade, across Rathdrum Prairie. Its course at Rathdrum is far over to the north side of the Spokane Valley.

Approaching Post Falls from the west, the pronounced scarp in gravel (50 ft. high) which puzzled me several years ago, is encounterd. This steep, west-facing scarp is composed of well-washed river gravel, stained to a depth of 8 feet, tho not decomposed. Two apparently correlative terrace-like features can be seen to the north and northwest, against the north slope of Spokane Valley. The summit of this scarp is nearly flat for at least a mile to the east, probably for ~~sev~~ several miles. It has very gentle undulations in it, a little more pronounced in the gentle southward descent to Post Falls, there being no scarp to the south as there is to the west.

The hypothesis above suggested; that these broad undulating ridges of gravel are Spokane in age, is going to require much less in the way of Wisconsin water. It is also going to require an ice-free Spokane Valley for a very great Spokane glacial river. If bursting of the dam of glacial Lake Missoula caused the scabland flood, the ice margin must have retreated from Spokane Valley, from the Spangle lobe, and probably from much of the lower Spokane Valley, below the city and from the Columbia Valley along the north side of the scablands as far west as Grand Coulee. This seems a feasible way to get water from Lake Missoula to enter all channel heads as far west as Grand Coulee. There is no field evidence against it. Indeed, there ~~i~~ is a lack of field evidence for the view that the ice was at its southern limit when the flood occurred. If the ice had stood at its farthest extent at that time, I- Lake Coeur D'Alene should have then overflowed to the southwest, 2- stream notches should have been cut a along the south slope of Spokane Valley (if the ice was then against the base of this slope), and 3- Mica Channel should have been the dominant channel, if not the only channel, for scabland waters.

The bar forms with a relief of 100 feet would thus be simply explained.

But if these bars were made by the water that flowed thru scabland channels, the water over the bars must have been enormously deep. The bar tops are 2100 to 2150 and the highest berg-drifted erratics at Mt. Hope are 2550. 400 feet of water flowing vigorously enough to make these bar forms with large cobbles and even boulders in them, and nearly four miles wide at Post Falls, is a conception as shocking as the scabland flood was originally. Can it be supported? Where are the water marks along these rocky slopes 300 to 400 feet above the bar tops?

But if the water which was deep enough to make the bars (100 ft. minimum) did not escape across the scablands, it must have gone down the Spokane to the Columbia. And if it did this, there should be bar forms 100 feet or so above the Wisconsin valley train along it. Are there?

There is no third alternative!

But perhaps these are not bars! They certainly are not erosional forms and if not bars, they must be gravel-covered moraines. Are they?

Seven or eight large cobbles of the granodiorite porphyry found in a quarter of a mile of roadside cobbles on top of the bar two miles west of Post Falls, near Signal Point.

Post Falls to Athol July II I929

The large bar-like gravel form north of Post Falls is composed at its southern end, next to the river, of fine gravel from bottom to top, about 50 feet. Bedding is very poorly exposed but is horizontal where shown except in one place. Here it is foreset, dip being eastward in the plane of the section. Some large boulders have come out of it and many cobbles but it is a remarkably uniform fine gravel in general.

The summit of this bar-like form is nearly I00 feet above Post Falls (2265 A.T.) but since the town is down in a more recent valley, the really significant height is that of the western scarp, 50 feet above the plain to the west. The northwestern slope of the gravel deposit is less marked but still a conspicuous slope. It is littered with boulders, one at least 8 ft maximum length seen. This boulder-strewn slope apparently continues diagonally nearly across the Spokane Valley, not far from the 2200 contour, tho more directly. A mile or so south of Rathdrum, it is about 60 feet high and its top is nearly I00 feet above Rathdrum.

At RAthdrum, is a channel half a mile wide, the floor of the Wisconsin glacial river from the moraine at the south end of Pend Oreille Lake. This channel, now carrying no stream, is the lowest feature of the great gravel fill of Spokane Valley. It is very marked a mile and a half south of Hauser where its higher bluff, on the south, was read as II0 feet high. The floor here is strewn with boulders, some of them in bars.

Spokane River apparently enters this channel at or a mile or so below the hiway bridge called the Spokane Bridge on the topog. map.

A very interesting and important bit of topography is a broad hill two miles east of Post Falls and just north of the hiway and NPRR It has a steep scarp I70 feet high, facing toward the west at the prow-like terminus. No sections in the hill were seen but none are needed. The summit is well marked moraine topography, with very good kettles and hills whose immediate local relief is 50 ft. Traced eastward, the high surface (which looks plane from a few miles away) descends more gently to the general surface of the southern part of Rathdrum Prairie. This also is morainic. Indeed, weak morainic sag and swell topography characterizes the prairie for two or three miles to the north, very gradually blending into what is probably the outwash plain surface correlative with the moraine. This in turn breaks off over the 60-foot scarp to the low channel just south of Rathdrum. By this correlation, the big broad gravel mound north of Post Falls is the western continuation of the outwash of this moraine.

But this isht correct in some way for the big gravel mound north of Post Falls abuts against the steep west face of the moraine and thi steep hiwgh high face is very probably an erosional scarp. Spokane River on the south and an empty channel on the north lie at or close t to the scarp bases and join at the west end.

The moraine summit reaches 2400 aneroid set at Post Falls half an hour earlier. The USGS map rings it with 2300 and has the 2200 around the base of the high scarp so it may well reach almost to 2400 on the map.

What bearing does this fragment of moraine, and the lower moraine to the east and north, have on the hypothesis that the gravel mounds north of Post Falls, at the mouth of Liberty Lake valley, etc., are bars in a great glacial river that spilled over to the scablands? It seems to debar the hypothesis, for all this moraine must have been overrun by a river which stranded erratics up to 2550 and whose channel floors at the heads of the scabland routes are nowhere lower than 2450.

The scabland rivers either took origin from a lake-like river in Spokane Valley (if that valley was ice-free when the flood occurred) or these big bars and the moraine are younger than the scabland. This point must be cleared up.

Several new and very interesting finds in the vicinity of Lone Mt. Both Fish (Twin) and Spirit lakes are dammed by moraine. The moraine-marked area extends from the west base of Lone Mountain to the shore of Fish Lake which is 100 feet lower. It is shown by the contours on the Rathdrum sheet. Around the northern end of the Mountain, is a broad shallow channel, part of it with well-defined channel walls. This channel comes off the main prairie south of Athol and swings around between Lone Mountain and the high mountains west of the big valley to include the lower part of Fish Lake and to re-enter the main prairie flat near Sheridan.

North of this channel is moraine on the valley floor from the lower end of Spirit Lake eastward to within two miles of Athol. It is very well expressed, a great series of nearly north-south elongated ridges and sags with a maximum observed relief of 80 feet. The moraine is very gravelly. Its material is stained to a depth of at least 6 feet but there are no marks of running water on it and little evidence of filling of the kettles. Most of the slopes are steep. Extraordinarily large boulders of granite lie on the moraine, some of them 20 feet or more long.

The highest part of this wide moraine belt (five miles max.) is above 2600, all of it lies above 2500 which marks the northern margin of the channel around behind Lone Mountain.

In vigor of expression, this moraine should be Wisconsin in age. It grades out eastward into outwash, also above 2500, to within less than ~~1/4~~ a mile of Athol. There it breaks off abruptly in a scarp 160 feet high, the scarp overlooking ~~theundoubti~~ the undoubted Wisconsin valley train at Athol.

The moraine therefore must be pre-Wisconsin in age. The Athol plain is traceable two miles farther north right into the Wisconsin moraine which is considerably less vigorously expressed. The scarp records more than 200 feet of erosion thru the middle of the valley, removing the rest of the outwash plain (if it is such) which accompanied the Spirit Lake moraine. Relations are similar to those two miles east of Post Falls. The Post Falls moraine is 2400 (or nearly so); the Spirit Lake moraine is 2500 to 2600 and 16 miles farther north. It doesnt seem correct to correlate the two, for any lobe of Cordilleran ice reaching to Post Falls would have its moraine much higher at Spirit Lake. Yet there is no evidence that they are of different ~~age~~ ages, and the upper limit of drift deposited here (Spirit Lake) when the Post Falls moraine was made may well be hidden in the forest on the mountain slopes and these ridges on the plain may be retreatal, recessional.

It seems more probable that the outwash north of the low morainic area east and north of Post Falls moraine is younger than the moraine, rather than contemporaneous. The field relations can be better understood by this view.

Athol to Post Falls July II I929

Benches of gravel block minor valleys in several places along the northwest side of the big valley near Rathdrum. Two very pronounced ones two and three miles southwest of the town. One is nearly 2400 feet AT on its high valley-ward edge, 225 feet above the floor of the Wisconsin channel at its base. It has a low bench against its lower slopes 80 feet above the channel floor. About a section of land lies back of and no higher than this bench edge. Half of it is 25 feet or so lower and is marshy and without an outlet stream, tho a creek flows into it. The material, so far as exposed in road cuts and a gravel pit on the front of the scarp, is fine, well-stratified, well-sorted river gravel, horizontally bedded.

A similar feature occurs a mile farther down the valley, and the high bench can be identified at several places as far west as Hauser (Sucker) Lake whose valley mouth is partially constricted by a spur at this terrace level on the west side. Yet Hauser Lake (and Newman Lake to the west of it) is low and if these valleys ever were filled by the bench gravel deposit, they were eroded clean at the time the great high gravel fill recorded by these benches was eroded out of the main valley.

The upper limit of these benches apparently descends somewhat down the valley tho no figures were recorded to prove this. The benches should belong with the Post Falls moraine. If they do, ~~the~~ there has been ~~more~~ much more erosion of the high bar gravel on the ~~near~~ north side of Spokane Valley than on the south. It may be that the big bars on the south are younger; it may be that only lateral erosion by the river is responsible for the fragmentary character of the deposit here. The gravel is at least I25 feet higher on the north than in ~~the~~ the big bar north of Post Falls.

A splendid sharp-cut notch in a spur about two miles north of Rathdrum. A side-hill gash!

Not all of the bench-like forms seen along Spokane Valley are of drift or alluvial debris. One prominent one a mile southwest of Post Falls, 450 feet above the river, turns out to be simply a rock bench, littered with local debris and yielding only one undoubted foreign ~~sea~~ scratched fragment.

Whitebird and Pittsburg Landing July I3 I929

There is not a trace in either Salmon or Snake River valleys at these places of glacial water. Every form is normal, all materials are close to their source, no striae on any fragments. Apparently these long distances up and along crooked canyons deprived the back ~~ru~~ rush of its berg load and its ability to rearrange local debris.

Disappointing as it is to fail to get the record this close to ~~th~~ flood's upper limit, it is very significant that the peculiar deposits about and below Lewiston are absent in the Salmon and the Snake. This contrast indicates the operation of radically different conditions.

Debris accumulations in Snake River valley at Pittsburg Landing are almost wholly steep alluvial fans of coarse material. Sections in the large fan at Pittsburg Landing show locally derived, subangular material thruout. Even in the cliff at the tip of the fan, there is almost no well-worn material of the Snake. Granite boulders four ft. in diameter are common in the deposit. The gradient of the fan is too steep to drive up in high.

The fan is compound in that its growth has enclosed some low hills of rock and different parts of the fan have different characters and

altitudes. There are several flat places in the lower part that may represent Snake River planation.

Granodiorite boulders in Snake River Drainage.

Cobble bars of the Clearwater, the Salmon and the Snake were inspected in several places (the Snake only at Pittsburg Landing). Many and varied porphyries seen, especially in the Snake. Many of the right color and texture but mineralogically wrong. Only one cobble was found anywhere that might have been selected as a granodiorite porphyry of the type I have been collecting. So many others that are similar in a general way that it seems that a graded series might readily be made. This is quite different, as I remember it, from the porphyries in the high drift about and below Lewiston and it suggests strongly that they never came down any of these valleys. Furthermore, there are no angular forms of these porphyries, either in the bars or high on the slopes, while the high-level drift porphyries are all angular.

Anderson showed me a series of specimens of granodiorite, collected from dikes along the northeast wall of Pend Oreille Lake, near Hope. One was exactly the type I have been collecting from the berg-borne erratics and the high bars of Spokane Valley, the others were very close variants. The Pend Oreille valley seems to be a logical source.

Grangeville to Nez Perce.

Between these two places, the plateau is fairly plane and its local drainage pattern is very immature. One deep canyon and a few short tribs. lies between the two towns, draining to the Clearwater. Also there is essentially no loess on this part of the plateau. (Some anticlinal warps here.)

But north of Nez Perce to Orofino, the plateau has a good loess mantle, a few tens of feet thick on the average and a good maturely developed local drainage pattern. It seems that, like the Anatone region, the absence of loess (however that may be explained) means the absence of mature topography.

Kamiah Buttes – described by Anderson (1930) as stepfoot of an older lava

Clearwater River Valley July I5 I929

Between Agatha and Myrtle, at altitudes between I050 and I300, there are numerous fragments of non-basalt on the grassy slopes of the basalt hillside. Scratched fragments were found up to I250, quite definitely glacial. One quartzite cobble had both striae and chatter marks on both sides, oriented with the length of the cobble. Large granite boulders at I000. Most of the cobble-sized pieces are angular or subangular, many of the pebbles are rounded, some broken-round. Schist is present in the large variety of rocks represented and argillite and phyllite of typical Beltian facies and colors; maroon, red, green, are fairly numerous.

The rounded condition of many pebbles suggests that perhaps an old river gravel lies here also, and that only the angular and subangular pieces should be considered as glacial. All foreign material is fresh in appearance. (Nearly all)

Above Agatha, along the road, is a soil three or four feet thick, unstratified, containing non-basalt fragments, three pieces of which are striated. One rounded basalt cobble, found at about 950 or 975, is definitely striated with short, wide scratches elongated with the cobble. But these marks are on a definitely concave surface and, whatever their origin, they can hardly be glacial. They are distinctly different from the striae on stones in glacial drift.

In the mouth of the creek valley just to the west of the rounded spur which carries striated stones up to I250 is a remnant of a silt

deposit about 30 or 40 feet above the river, a silt which is dark brownish like the residual soil of the basalt and is unstratified but which contains angular fragments of non-basalt, two of which are striated and bruised. This seems clearly to be a part of the sought-for glacial silt up the Clearwater. The creek is about half a mile east of Firbluff station.

A mile east of Arrow along the highway, at an altitude of 1050 A.T., 230 feet above the river, is the glacial silt without doubt. It is about 8 feet thick and is limited to one exposure, Latah occurring on both sides. It is bedded, tho irregularly and with marked undulations. The coarse sand seems to be largely basaltic. Some of the silt is well impregnated with bits of rock. Silt color and is pale yellowish, not the deeper, darker color of basaltic soil. It also is much looser, like loess, while the darker material in the mouth of the creek valley is a bit cloddy, as tho more colloidal in character.

Above Agatha, there is no road along the Clearwater valley bottom as far as Ahsahka. From Ahsahka, one can traverse the valley floor to Greer where another interruption in valley bottom road exists as far as Kamiah. From Kamiah, the valley floor can be traversed by car as far as Harpster. All the valley that could be reached by car was traversed. The net result was that nowhere were glacial silts seen, nowhere were striated erratics found, nowhere were valley mouth bars discovered. Tho most of the traversed portion is below the 1325 foot upper limit of the flood, any conspicuous record left ~~he~~ here is now obscured by forest, covered by grass or eroded away. Perhaps one should not expect that these long valleys should carry th flood record at its crest level. A surface gradient is an essential factor and that could not exist in adequate amount as the water approached the upper level.

Tammany Hollow July 15 1929

The Hollow is a broad structural depression in the Lewiston plateau, about southeast of the city, at the head of the creek. Its floor is somewhat above 1300. Westward, it opens thru the creek valley, itself partly structural, to the Snake.

The Latah formation is ~~wid~~ opened on the north wall in the western part of the Hollow. It is largely white quartz sand and white quartzite pebbles. It is not a gravel; the pebbles are scattered or in thin layers only. Associated non-quartzite pebbles are thoroly decayed. No basalt found; a curious thing. This Miocene stream deposit has very well rounded pebbles; of 315 specimens, 15 were broken rounds. No cobbles or boulders in the deposit.

Glacially transported erratic boulders of a variety of kinds in the creek gravel at 1200 and thence downstream. Not abundant. One angular granite along the road.

The glacial silt is well exposed in a cut along the old RR grade a little west of the foot of the ~~Olive~~ Olson grade. It is 12 to 15 feet thick and is covered by two or three feet of dust, with columnar jointing. The silt is stratified, layers of very clean fine sand or silt alternating with layers of dominantly coarse black sand and of the silt densely charged with grains of black basalt and foreign particles The sliver and splinter shapes are pronounced. In density of the ~~cha~~ charging of black particles, this silt is unexcelled even by the Johnson Creek silt of the Walla Walla plain. The stratification is irregular and the strata are discontinuous, just like the stratification phases of the glacial silt everywhere. Altitude of the deposit not secured but certainly higher than the top of the Tammany Hollow

bar at the valley mouth.

The bar re-examined; new observations made and some changes in interpretation. Most of the bulk of the bar is made of fine gravel and most of the larger pebbles, the cobbles and boulders are irregularly interspersed thru the fine gravel. Even where the boulders and ~~co~~ cobbles are most abundant, they are well separated from each other by the fine gravel. It is in no sense a boulder of cobble bar, the ~~into~~ interstices of which are filled with fine gravel. It is rather a plum pudding texture.

With this arrangement, some of the genetic condtions may be defined. First-- the dominant fine material does not indicate sorting, it indicates only that here most of the stream debris was fine and angular. Second-- current sweeping along the Snake and eddying back partly into the mouth of Tammany was moving boulders three and four and even five feet in maximum diameter along the margin of the channel and yet not sweeping away the fine angular gravel on which and in which the boulders rest. Third-- the extreme angularity of the fine gravel is the consequence of fracturing of already rounded gravel. Not alone do the numerous broken-rounds attest this but there are features of the cobbles and boulders, which were previously overlooked that are very surprising, yet perfectly in harmony with the broken-round pebbles. The boulders and cobbles are very commonly marked by percussion scars or shells. These scars are on the edges of flattish forms. Many do not have them, many have but one such scar but some are fearfully pounded almost all around the edge. These ~~ma~~ marks can be duplicated almost perfectly by sharp hammer blows on the edges or by throwing the cobble forcibly against another. There is no possible doubt of their origin; they have come from pounding and ~~ba~~ battering of the cobbles and boulders on each other. The size of some of the shells is almost unbelievable. A common size is two or three inches across but many exceed this greatly. The largest seen was in a basalt boulder and measured 15 inches across at right angles to the direction from which the blow came. It is a shallow shell, no more than an inch deep. Do these proportions indicate anything ~~abo~~ about the character of the blow?

The entire face of the cut along the back side of the bar contains these battered cobbles and the broken round pebbles. Despite its ~~dif~~ difference in color and its north-dipping foresets, it is all one deposit. Its continuation north of the creek can be traced readily.

Another feature of this bar, not previously grasped, is the 20-ft deposit of yellow brown silt above the gravel toward the north end of the bar. The silt rests directly on the rough bouldery surface of the gravel deposit, some boulders a foot or two in diameter, setting up on top of the gravel, project for their full diameter into the silt.

The silt is well sorted, no scattered particles of basalt, etc., showing in it. It also is well stratified, with very definite but ~~ir~~ rather irregular bedding. Lenses of black coarse sand occur irregularly, the contact of sand on silt being so irregular that it seems like a cross section of miniature mountain topography. To add to the puzzle, clastic dikes can be traced up in the deposit, thickening with increasing height and some of them abruptly ending at various levels. This silt looks more like a normal stream alluvium, the cracks developing at successive intervals while the accumulation was going on per saltum, thus some of the cracks being filled and covered over before other cracks were formed. The dikes are composed of black basalt sand like the lenses. Yet there is no such sand on top of the silt today from which the major number of the cracks (coming to the top) could be filled. Such sand deposit may once have been present, and now gone by erosion.

Among the large boulders in the deposit, basalt dominates by far and large. Much of what was earlier called decayed basalt may be decayed hydrated phases of the basalt. One boulder 3 feet ~~to~~ long, of loess, sufficiently indurated to need a hammer to break it up, but not marked thruout by rootlet marks, lies associated with boulders of equal size but composed of basalt. Brevity of action is absolutely required for this boulder to occur in this deposit.

The percussion marks of ordinary rolled cobbles are rarely found on the cobbles of this bar. Perhaps they were not looked for carefully enough. The smooth worn side of these cobbles certainly should have them as records of their experiences before the battering episode occurred. But the blows struck during this episode seem to have yielded complete fractures, rather than incipient ones. The source of the blows surely was other cobbles and boulder material. The cause of the blows was current action. If the cobbles were rolled, how rapidly would they have to move to produce such percussion? As rapidly as in a cascade or rapid, certainly. Do smoothed cobble, going thru a rapids, suffer such percussion chipping? If not in a rapids, then there must have been bodily lifting and dropping of the cobbles and boulders. And no rapids are available, either up or down stream.

Lewiston and Clarkston terraces. July I6 I929

Cobbles are plentiful in the gravel bluff just south of the business district of Lewiston but they are not battered with percussion flake scars. The gravel is well sorted in foreset strata of uniform character. There are no huge boulders in a matrix of fine gravel as in Tammany Bar's foresets or horizontal strata. There are no diversely stratified beds, truncating those below and dipping at various angles as in the Clarkston gravel. There are no intercalated silt beds. My former interpretation still seems best; that the delta-bedded Lewiston gravel is older than the glacial flooding, tho the percent of broken rounds in it is very high. If they were all freshly broken rounds, as in Tammany, it would be difficult to call them older.

The Nave pit re-examined. Plenty of upstream foresets here and in the river bluff for a quarter of a mile to the north. The cobble rejects contain a number with percussion flake scars, some with several. But there isnt the abundance of these shapes here as there is at Tammany. Nor are there so many broken rounds in the smaller pebbles. Angularity, however, is the dominant character of the fine gravel.

Silt up the Lewiston grade to about I000. At I500, material which looked like silt from the moving car, proved to be loess.

Thorn Creek Valley July I6 I929

Silt with plenty of particles of granite, quartite, etc., is abundant along the road three miles down Thorn Creek from Thornton. It occurs very close to 2250 A.T. ~~It~~ In it are several cobbles and small boulders of non-basalt and one piece of the granodiorite porphyry. This find supplies a need, for Thorn Creek by the flood hypothesis, should have these silts somewhere above 2I70, the uppermost limit along the head of Rock Creek.

Cache Creek Valley July I6 I929

Silts farthest up Cache Creek were found in the tributary entering from the south, half a mile above the junction of the two valleys. The silts are only faintly distinguished from the loess for the content of tiny pebbles and coarse grains is very low. Four non-basalt pebbles were found, one a granite. Altitude by aneroid was 2765, (2285 A.T.) Malden reading 2565 aneroid. Correct this for A.T. when Malden altitude is secured. Malden 2095 - CM+StP profiles.

Two miles south of Malden a diagonal road crosses Cache Creek valley, leading to Rosalia. Up the east slope of the valley along this road, the glacial silt is very conspicuous in 6 foot cuts up to 2700 aneroid, 2220 A.T. At and above 2710 aneroid (2230 A.T.), nothing but loess was found in the road cuts. Numerous pebbles and cobbles of various non-basalts occur in the lower cuts. This silt's upper limit is I35 feet above Malden Station (2210 A.T.) and somewhat more than that above the valley floor. Nothing but a glacial river I35 feet deep will provide the great turbulence to put this debris two miles back in a tributary valley at this altitude. In every way, this find fits into the demands of the flood hypothesis and in every way, it is impossible to explain by any other hypothesis yet proposed.

The glacial river overflowed the rock hill just south of Malden, leaving a small loessial island where the Malden water tower stands but stripping off all the Palouse soil down the south slope into the mouth of Cache Creek and building a bar there which encloses an undrained depression.

2220 A.T.

Squaw Creek July I6 I929

No silts were found in this valley but a number of erratics up to 2700 aneroid (Malden 2565 aneroid). One slab of Belt argillite, a small boulder of the granodiorite porphyry and a striated quartzite, cobble.

Waverly July I6 I929

The flat on which the village stands carries the glacial silt at 2380 A.T. This is the first find of this pebbly silt in Latah Cr. valley and is very welcome. It shows that the same aberrant conditions of unbelievably muddy water existed in this so-called glacial lake ~~well~~ up toward the head, as it did in every other back-water ponding of the flood. This was no slack-water lake. How deep was the water in the outlet channel across the divide? Cant this be determined by examination of small tributary valleys, reached by road and reading from Spangle?

Spokane to Mt. Hope to Spangle July I8 I929

Some new conceptions this afternoon that promise to help in correlating the glacial history of the Spokane Valley and the scabland channel heads. The valley of Latah Creek is the connecting link and has never seemed to have characters of either. The drainage of Latah flows northward, toward any invading Cordilleran ice. There never was any glacial water flowing down this valley, tho the valley contains huge amounts of glacially derived gravel, sand and silt, stream-bedded. No stream flowing northward is permitted and no stream ~~valley, and with outlet only thru Pine Creek channel, whose floor is between 2400 and 2450~~ flowing southward seemed possible, up the gradient of the valley and with outlet only thru Pine Creek channel, whose floor is between 2400 and 2450, 500 to 600 feet higher than the lowest of

these stream-laid deposits. Yet stream waters are largely responsible for the stratified materials in Latah Valley.

Beginning with the high bank of gravel along the NPRR on the east side of Latah Valley, these stratified deposits, traced southward, become more and more sandy toward Duncan and beyond Duncan are stratified silts. Not complete sections of all valley walls could be made of course, but for what was seen, the generalization is good. And nothing was seen to indicate that there was more than one episode of deposition of this gravel, sand and silt.

The gravel in the cliff along the NPRR east of Latah Creek has been described in a previous season's notes. Its upper surface is not a flat terrace top but is undulatory. It is largely built over ~~and is c~~ by a residential section of the city and is difficult now to interpret, but this surface seems to be the product of later dissection. The altitude of the highest is about 2370, whence it descends to 1900, the creek valley bottom. Foresets in this gravel and in other gravel and sand of glacial origin farther south indicates southward flow of the depositing water.

It now seems probable that the gravel in Latah Valley in Spokane grades into the thick sand deposits five miles or more south of the business district and these into the silts (with striated and bruised erratic pebbles) about Duncan and as far south as the road crossing of Latah, five and a half miles east and one mile south of Spangle. All seem to be a product of a huge volume of water flowing southward toward Pine Creek channel. The new data (Cache Cr. Valley) regarding depth of water in the Pine Creek channel (135 ft. above station at Malden) indicate the hugeness of the glacial river across the col between Latah and North Pine creeks, and the combination seems to demand the abandonment of the idea ~~that a L~~ of a Lake Latah, for which North Pine Creek was the outlet. Instead, the whole of Latah Creek from its mouth to the North Pine col seems to have been filled deeply with glacial outwash carried upgrade along the valley bottom by a great river. In support of this is the presence of fairly well marked scabland surfaces up to 2500 east of the Spangle-Mt. Hope road crossing (five and a half miles of Spangle). They are right in line and right in altitude for a river headed for the col, a river using lower Latah, reversed.

Such a river, if ~~equally~~ as deep on the col as at Malden, would have had an upper surface of about 2550 over the col. This is what is necessary to get the erratics floated back to Mt Hope at 2550. And erratics stranded there at that altitude demand such a depth of water in the channel or else an initial channel floor much higher than that left at the close of the episode.

New data about Mt Hope are very interesting. Erratic cobbles, pebbles and small boulders were found on the hilltop three quarters of a mile south of Mt Hope at 2550 plus. The pebbly loess or silt in fine development was found at the head of the grade up from Duncan at about 2400. This was five and a half or six miles northwest of Mt Hope. The upper limit was not carefully sought for but should be easy to find for the silt at 2400 is 7 feet thick and very sharply marked off from the loess by its gritty and pebbly content. The road crosses a hill above 2650 about five miles northwest of Mt Hope. This should take one above the upper limit of the flood silt.

The silt in the valley bottom, well laminated tho not definitely varved, contains a few erratic pebbles and is more like that of Lake Missoula than anything else seen in the vidinity of Spokane. It is quite unlike ~~anything that~~ the pebbly silt 300 to ~~400~~ 350 feet above it. It and the sand and gravel associated seem logically to be a product of ordinary melting and outwash from the first blocking of Latah up to

88% angular + subangular
9% + broken-round
2% – round

} Tammany Bar fine gravel.

the maximum of the glaciation. This must have filled the valley up nearly to the level of the north Pine outlet which, theoretically, was the dischargeway. Then, with the beginning of the retreat and the bursting of Lake Missoula, came the big flood and the spreading of the berg-borne erratics and the pebbly silt over the lower uplands up to 2550 and perhaps a little more.

East of Spokane July 19 [illegible] 1929

The westernmost prominent spur of granite on the south edge of the Spokane Valley lies just west of the Chester embayment and the Milwaukee RR route thru the Mica pass. This spur is largely bare granite up to 2900 at least and perhaps to 3000. There was no opportunity of reading it closely either from map or aneroid. But there is a pronounced break here, all the slopes below being largely bare rock and all the slopes above being largely covered with soil. What ledges do outcrop are very much decayed granite or gneiss while the ragged knobs below this altitude are fairly fresh rock.

Furthermore, the bare and ragged lower northern part of the spur is cut by about a dozen transverse notches, as much as 75 feet deep. Some of them bifurcate, one group consists of two on the east slope and three on the west; Three or four marked rock basins with cattail or sedge marshes and standing water occur in these notches.

West of this group of notches on the bare spur and almost as high is a very definite bench of debris, covering 40 acres or more. Its valleyward margin is very steep and 300 feet high. Most of its surface is flat and cultivated. A pronounced broad ridge 40 feet above the flat encloses it almost completely between itself and the normal erosion slopes of the higher hills to the south. The broad ridge is either a moraine or a high bar. No morainic forms were seen on it tho there are boulders here and there. Most of it appears to be a granitic sand. No good cuts and no structure seen. Its location to the lee of the bare, gashed spur suggests a bar origin.

Above the flat back of the broad ridge are scattered erratic boulders for a hundred feet of altitude. Probably these continue all the way over to Moran where there is glacial drift. But the spur itself, above the bare portion, yielded no evidence of glaciation. How high is the drift about Moran?

A large granodiorite porphyry boulder found on the bare shoulder. It was the only erratic recognized here.

The main valley flat, west of the northern part of the rocky spur has a bar on it about 50 feet above the little enclosed flat at its very head, and according to the map, 2300 ft A.T. at the highest place.

West of this embayed flat is a considerably smaller spur of granite. It was not climbed but the ragged granitic scabland topography is conspicuous on the lower part, even thru the yellow pine forest.

About a mile south of Trent and south of the Spokane River is a group of granitic knobs in the midst of the gravel plain, here the lowest of the valley gravel fill. Anderson, Large says, reported glacial striae on these knobs. Large guided us to the place. The polished surfaces remaining are clearly only the work of water and its debris. Tho smooth, the surfaces are irregular with low ridges and depressions and there are no striae. Many more surfaces were found than Large knew of. A few places found where channelways a few inches deep across and a few inches deep were still decipherable. Remnants of two potholes found, each with the polish remaining in places. No glacial ice is recorded here in these markings. The highest hill is probably 100 feet above the river, perhaps that high above the surrounding gravel plain.

The Post Falls gorge, from which the river has been diverted, has similar surfaces and shapes. It also is a fine narrow canyon in the gneiss, much better than any of the high-level gashes seen this forenoon. But it and the associated rock knobs and earlier abandoned channels are of the same category as those on the spur.

The Post Falls bar either drops off to the east or, more probably has been eroded away on its eastern part by the glacial stream which made the high steep scarp on the north and west of the Post Falls moraine remnant, two miles east of town.

The material of the moraine, exposed in cuts on the steep road up near the west end, is rather small river gravel. No clean cuts. A very few boulders on top, nothing at all like the coarse cobbly and bouldery river drift of the Spokane Valley farther west. If it were not for the topography on top, I would call this a high level outwash terrace. Possibly it is a pitted plain, but the topography does not support this interpretation. For it is definitely ridged. The ridges are elongated nearly north-south, a position which does not support the idea that the ice which made it came from the north.

The top of this moraine is not far from the altitude of the morainic benches along the south side of the river here. It looks as tho the moraine had once extended completely across the course of the river to the south. Since the stream now has a wide valley here, it has required plenty of time to remove this missing part of the moraine.

Vicinity of Lake Coeur D'Alene July 20 1929

Drifted erratic boulders, about twenty of them, stranded on a little flat at 2691 B.M. near Silver Beach. The granodiorite porphyry is among them. A few with poor glacial markings. No trace of any drift higher on this slope. This is the highest drift yet found about the lake and looks like an upper limit. Its failure to occur higher points to berg drift, not glacial drift. The closeness of this figure with other maximum altitudes of such material about the lake also indicates this. 2691 is nearly 2700, nearly 150 feet higher than the Mt Hope erratics and helps to make the picture of a glacial river, not a glacial lake, connection between Lake Coeur D'Alene and the scabland channel heads. This is required by the flood hypothesis.

A quarter of a mile east of the B.M. along the road is a flat at 2610, on which there are very many erratics. The flat bears a silt full of pebbles and coarse grains of rock, of various kinds. It seems identical with the glacial pebble silt except that its matrix is hard and clayey, not friable like the loess, nor as light colored. The deposit is identifiable for 30 feet up on the slope above the flat.

It is fully possible that this pebbly silt is the product of slope wash, etc., since the erratic debris was deposited. It seems almost impossible that a turbulence adequate for transportation of this mixture could have existed this far up a valley like the Coeur D'Alene. Yet this is precisely what the valleys along the east side of scabland all show.

Another high point for berg drift is about a quarter of a mile still farther east. Erratics were found here up to 2695 A.T. But no silt.

The divide between Blue Creek and Wolf Lodge Creek at about 3000 carries large numbers of poorly worn but stream-carried cobbles, chiefly of quartzite. The material is very much decomposed for quartzite, almost a sandstone now and much stained. It belongs with the stream gravel seen south of Mica, Idaho, and somewhere in Anderson's series of old base levellings. It isn't glacial.

The erratics west of Beauty Bay in the saddle crossed by the road ~~also~~ along the south side of Wolf Lodge Bay, occur at least up to 2590. The highest found was a granodiorite porphyry. Down the relatively gentle grade west of this saddle are pebbly silts and sands in the shallow ~~road~~ cuts. Two silt samples were collected, the lower one coming from a prominence rather than a re-entrant along the valley wall. It thus is not so likely to be a reworking.

Near Echo Bay a fine gravel and sand deposit is cut by the hiway. The debris is 99% basalt and very angular, tho largely fresh. A few very pronounced slivers found but most of the angularity is not exceptional. Foresets well shown, dipping toward the lake. Five feet of rust overburden, largely of alluvium with angular fragments of basalt. This gravel seems very likely a shore deposit, perhaps deltaic. A granite boulder, resting on top, may record it as older than Spokane.

Nothing more than water-laid debris or silt deposits seen from Echo Bay to Harrison. Ferry taken here to a point directly west across the lake and road thence to ~~to~~ Worley, Ford and Coeur D'Alene. No erratics seen from car up to 2600. A search at that altitude revealed no silt and only one small erratic pebble. No trace of glacial waters about Worley. A large granite boulder three or four feet max. diameter, lies along the road south of Ford, altitude about 2575. Many more farther down the valley. But no pebbly silt.

The vicinity of Bellgrove is an undulating plain whose B.M. at the north end (the high end) is 2585. Plenty of erratics all over the plain. Also pebbly silt with bits of non-basalt and non-gneiss. The highest erratics lie at 2685 on the east slope of the enclosing pre-basalt hills at the north end of the flat. One of these is a boulder of the granodiorite porphyry. The local rock here is hornblende schist and vein quartz. Several erratics at the BM are striated and glacially bruised. Slopes ~~scoured~~ searched above 2700 but no foreign material found.

The Mica flat, five or six miles farther north, is about the same altitude and is similarly strewn with erratic boulders and bears a better-marked pebbly silt, a material very like that found at 2691 north of Silver Beach. The upper limit was not found here for the slopes above 2600 or 2650 are covered with brush.

Now we know that the upper limit of any glacial water in Lake Coeur D'Alene basin does not exceed 2700, tho it comes almost to it. We know that glacial pebbly silt occurs up to 2500 and 2600 about the north end of the lake, That the erratics are unweathered and that some are glacially marked. There must have been glacial ice or ~~gl~~ glacial moraine or a vast volume of glacial water in the valley north of Coeur D'Alene Lake to impound this water to that altitude. Yet the outlet must have been thru that valley or at least along the south wall of the valley, with ice as the north wall of the channel. It seems absolutely necessary to find field evidence of this discharge, tho of course one may argue, without such evidence, that the discharge was over, thru or under glacial ice out in the valley. The important points thus far established are

1- 2700 ~~was~~ is the upper limit of the ponding in Coeur D'Alene Lake valley,
2- the existence of the pebbly silt up to 2600 in the northern part of the valley,
3- glacial ice itself very close to closing the north mouth of the valley

A delta of poorly worn gravelly and cobbly debris lies just west of the former site of Ft. Sherman. A pit exposes good foreset bedding in the steep southern face. The angle between the frontal slope and the top slope is 250 feet above present level of the lake, nearly 2400 AT. Traced northward, the delta surface has abundant knobs

of basalt 5 to I0 feet above its plane surface. North of this is the northern slope down toward theriver, composed of basalt. This delta is at least 300 feet lower than the upper limit oferratics , and it dates from a somewhat different ponding level, tho not necessarily from a different glaciation. Thegranodiorite porphyry found in this delta's material. Many boulders of granite on top, tho most of the large boulders are of basalt.

Vicinity of Coeur D'Alene July 2I I929

The north side of the shoulder between Cougar Creek Bay on the south and Spokane River on the north is a broad ledge of basalt reaching a little above 2500 feet. Theridge itself reaches 2800 and more, and is composed ofgneiss, well covered with residual soil. The basalt bench has numerous cliffs and knobs of bare rock and its debris cover, where present, is glacial dfift. Striated erratic cobbles and boulders were found up to 2600 or 2650 on the gneiss ridge above the basalt bench, and thebench itself carried definite small moraine ridges andundrained depressions.

There are two notches thru the gneiss ridge, south of the basalt bench, andnot two miles west of thedelta at the east point of the shoulder. They are 2650 AT at the bottom. Neither one isa gash. Both are simply saddles but one has much bare rock in the bottom and on thelower slopes, an abnormal thing. But to use these notches for glacial water or lake water seems difficult because of the lack of real trenching and thepresence of a residual soil cover on the slopes. They are lower, however, than the highest gfloated erratics in Coeur D'Alene lake basin and, if they ~~do not~~ were not used, they ~~should~~ must either be younger features (impossible) or they must have been blocked or had drainage thru them blocked by glacial ice. Glacial moraine at 2500 and abundant erratics to 2600 or 2650 just north of them seems to indicate that the idea of blocking is correct. Perhaps a little spill thru isindicated by thebare rock in the bottom of one notch but it apparently was inconsequential.

The basalt bench isvery interesting and suggestive. It has a very irregular surface, a real channeled scabland durface, with knobs and~~kettles~~ buttes andridges separated by anastomosing channels, two of which are very definite. These channels run along thebench, not across it toward the much lower land along the river. The local relief is as much as 50 feet. Altitude ranges from 2400 to 2500+.

Since the bench carries glacial moraine, one could think that this scabland is the product of glacial plucking and thechannel forms only a simulation of such. But there are two serious objections to this view;

I- a spur ofbasalt of similar character, just south of the lower end of Hayden Lake, was traversed by the ice without production of any such topography. So with thebasalt bench east of Ramsey, that west of Hayden Lake andmany square miles along the north edge of the plateau west of Spokane.

2- If the basalt was plucked out by glacial ice, it here would be carried in only one direction, southward, uphill. There is no such quantity of basalt in thelimited drift bank against this wall.

There seemsno escape from the conclusion that these are true water channels and that the debris was carried laterally, along the ~~ice~~ ice or moraine were banked up along thenorth edge of the bench.

Yet there is good moraine in these channels. One boulder of basalt I5 ft high and I5 by 25 stands almost in themiddle on a low morainic ridge. The channels were here first; the drift was deposit-

ed later. Just what this means isnt yet clear. But it definitely establishes a sequence here. It reminds one forcibly of the low morainic ridges on Sunset Prairie, even in the head of one of the channels here ~~(Meadow Lake or Silver Lake)~~ (Willow Lake).

Drifted erratic boulders and cobbles are abundant on the hill between French Canyon and Fernan Lake, up to 2665. Many are well striated. But no moraine topography seen here, or at least no more than faint suggestions of it. Apparently these erratics are berg-carried. Above their level, the fields are full of the weathered subangular to subrounded quartzite pebbles and cobbles seen south of Mica and on the divide between Blue Creek and ~~Silver~~ Wolf Lodge Creek. Their uniformity of material, their advanced degree of weathering, and their lack of striae make confusion with the glacial erratics impossible.

The Post Falls moraine topography is well marked on the eastern and lower end, and is in contrast with the very subdued knoll and sag topography of the prairie to the east and and to the west. If the lower prairie about here is morainic, it is only weakly expressed ground moraine. The big moraine hill has cobbles and boulders scattered on it, some of the boulders very angular. But most of it is composed of rather fine river gravel.

No definite moraine ridging along the east side of the prairie from Coeur D'Alene city to Hayden Lake. Some places show faint ~~ri~~ ridges subparallel with the rock hill base. The lower slopes of these hills are scrubbed and scabby in places but do not approach the features on the spur west of Chester. The low ridge in the mouth of Hayden Lake valley is flat-topt and is composed of well-washed, well-stratified gravel in the only cut seen. The exposure is nearly the full height of the terrace. The gravel is bright only in the lower part. Its upper rusty zone is 6 to 8 ft or possibly 10 feet thick.

Rathdrum Prairie Sunday PM July 21 1929

The problem of this prairie is solved. It is ground moraine of exceptionally pebbly till. Its topography of low sags and swells would be good enough for ground moraine anywhere if the sags were accentuated by swamps and ponds. But the dry climate and porous soil do not allow this. Where railroads cross the prairie, their cuts and fills show clearly that the relief is adequate and properly arranged. The abundant large boulders are better explained by this hypothesis than by the idea of glacial river transportation. Furthermore, many of these boulders are not rounded.

The only good evidence not found for ground moraine is striated boulders and till structure. Striae were not looked for, and there are no adequate sections to show till structure, if it were present.

The excessively gravelly character of the material ~~for several~~ has made me think for several field seasons that this prairie was outwash. The distribution of the minor local relief in a gently sloping plain was also deceptive. But now this ground moraine is seen to harmonize with the very gravelly character of the Post Falls T.M.; and the Polson moraine may be brought in for comparison. Apparently, these intermontane valleys contained large amounts of stream gravel when the ice advanced, and this, rather than angular rock material ground off a rock bed, supplied the drift.

It is to be noted, however, that the extreme south margin of the drift, on and above the basalt bench described this forenoon, is not strikingly pebbly but looks much more like an ordinary boulder clay.

Across the Rathdrum Prairie ground moraine is eroded the Wisconsin spillway. It heads abut two miles north of Athol and its course to the west edge of the Rathdrum sheet is marked by the course of the main line of the NPRR . Thus it swings from the middle of the valley at Athol to the east side at Chilco (a Spokane International RR. station due east of Ramsey) and back to the west side at Rathdrum. Near Sheridan, it is 125 feet below the Rathdrum Prairie ground moraine. At Athol, its scarp to the west of town is 125 feet high. Its floor is irregular, in places fluted, but not terraced so far as seen. The prominent scarp covered with huge boulders, noted about a week ago north of Liberty Lake and Post Falls, is the eastern bluff of the Wisconsin glacial river. The width varies but averages at least a mile. Near Athol it apparently reaches completely over to the rock hills near the foot of Pend Oreille Lake, a width of four miles.

Is it a valley train? The answer should be NO. It is an eroded channel with an indeterminate, and probably indeterminable, fill of Wisconsin gravel in the bottom. Farther west, out on the Spokane sheet, it probably changes to a valley train and so continues down the Spokane Valley toward the Columbia.

The so-called high bar directly north of Post Falls is very probably moraine. It has shallow but undoubted sags in it and no channel scarps across it. Starting here, one remains on this slightly and gently undulating topography all the way eastward around the north end of the Post Falls T.M. to the main area of the ground moraine. The only break is in the channel that comes along the north side and ~~we~~ west end of the Post Falls T.M. This channel appears to head on the ground moraine, not to cross it from the north. The prominent west-facing scarp of the so-called Post Falls bar may be a scarp cut by the Wisconsin waters, tho it also may be an original front and it may be that it is like the channel just noted around the P.F.T.M., a product of the waters escaping during the closing stages of the Rathdrum Prairie ground moraine glaciation.

Where the big bars of Liberty Lake, etc., belong is yet to be definitely decided . The relation of the Rathdrum Prairie ground moraine to the Post Falls terminal moraine is also uncertain. The age is also uncertain, and the relation of the whole to the Spokane Flood.

It may be suggested now that the Spokane Flood was earlier than the building of ~~either~~ the ground moraine and the terminal moraine, the two assumed to be of the same age. This would put the flood back another glaciation, and would ask for a glaciation for which there is at present no known morainic material in this valley between Pend Oreille and the channel heads. But this would allow the ground moraine and terminal moraine to exist unmodified by any bursting Lake Missoula and it would allow the morainic deposits to lie in the scabland channels of the basalt bench and on the basalt plain of Sunset Prairie.

But since the Post Falls and Rathdrum Prairie moraine and ice obviously made the 2700-foot glacial lake in Coeur D'Alene lake valley this lake cannot by this explanation be made contemporaneous with the scabland of the plateau.

Spirit Lake Moraine July 21 1929

The plain east of this moraine and 125 feet higher than the Athol channel is not outwash as was thot a few days ago. It is ground moraine. Its topography is similar to the Rathdrum ground moraine, its position on the valley side of the Spirit Lake T.M. is correct for ground moraine and wrong for outwash, and it is composed of very gravelly till A section in the scarp west of Athol shows 75 feet of ~~th~~

this till, overlying a silt deposit which may be still older or may be a lakedeposit made in front of the Spokanem Spirit Lake ice andoverridden by it. It seemsvery probable that the Spirit Lake terminal moraine ,which iscontinuous with that west of Lone Mtn., is the same in age and is also the same as the Rathdrum Prairie ground moraine and the Post Falls terminal moraine. The ground moraine just west of the Athol channel was traced north onto the Sand Point sheet. Here it is a great channel cut into it, its scarp nearly 300 feet high, and Hoodoo lake and Hoodoo channel at the foot. A very marked terrace exists midway down this scarp on the south side of the Hoodoo channel (see Anderson, who isright about the Wisconsin discharge thru it at a later stage of Wisconsin glaciation). This terrace is an extension of the Athol channel level and should be a record of the earlier Wisconsin waters escaping from a Hoodoo lobe of Wisconsin ice. Where is themoraine of this Hoodoo lobe?

Granting that there was a Spokane Flood and assuming that itwas caused by the bursting of glacial Lake Missoula, there has been no glacial Lake Missoula since the Rathdrum Prairie ground moraine was deposited, unless stagnant ice protected the glacial topography.

Vicinity of Spirit Lake July 22 1929

The moraine, traversed northward from Spirit Lake for about 3 miles, ends abruptly in a scarp more than 200 feet high, north of which isthe floor of a channel leading west from Hoodoo Valley thru Spirit Valley to Clark Fork at Newport. This scarp is continuous with the one at Athol and that south of Clagstone. It is an erosional scarp without doubt and it isolates the area of moraine about Spirit Lake and Twin (Fish) Lake from other moraine of the same age by Wisconsin channels. To a surprising extent , this tract of moraine is separated from the mountains to the west by a fosse. The slender north end of Spirit Lake is in thisfosse which continues completely thru to Spirit Valley, whereit opens onto the floor of that channel. A dry valley, very similar otherwise to the one at the north end of the lake, extends a mile toward the south from the east end of the lake. And the lower one of Twin Lakes is in the fosse.

This is no erosional valey. It isvery variable in width and it has morainic topography on its slopes. The ice lobe in the great valley may have crowded up on the mountain slopes but it did not drag up its basal debris quite to the foot.

A traverse up Blanchard Creek valley shows glacial drift almost to thehead of the valley. The granodiorite porphyry is present in this drift. A series of very good sections up the serpentines to the summit between Elk and Blanchard shows nothing but weathered granite and gneiss above the upper limit of this drift, 2630 A.T.

The Spirit Channel or Blanchard Channel is 75 feet below the drift in the entrance of Blanchard Creek to the channel valley. Tho this looks very much like erosion by Wisconsin waters and almost doubtless is such, the channel does not show the trench-like character to be expected. The slopes are gentle. Yet Fish Lake and a swamp occupying the lowest of the channel tell clearly of an abandoned glacial river channel. The only alternative to theidea of glacial river erosion for these Wisconsin spillways is that of interglacial stream erosion. This seems totally inadequate.

Foreset gravel dips into Spirit Lake from the east end, also into Fishm(Twin) Lake valley. Spirit Lake surface is I30 feet below the level of the moraine where thetown stands. This is a measure of the depth of the fosse also.

The apparent channel from Eight Mile Prairie around back of Lone Mountain is probably ground moraine, the cast of an ice tongue. It has morainic expression in many places and hangs 110 feet above the bottom of the Wisconsin channel at Rathdrum.

Rathdrum Prairie July 22 1929

A ledge of basalt about 100 feet high outcrops along the east edge of the Wisconsin spillway just five miles directly east of Rathdrum. Its surface is but little more than a mile wide and east of it are low granite or gneissic hills with a deep residual soil, on which lies the Spokane till with abundant unweathered erratics. This continues eastward to the head of Hayden Lake, the highest altitudes reached being 2900. Evidence here that the higher land between Hayden Lake and Rathdrum Prairie is not all basalt, and that the Spokane ice did not eroded deeply in passing thru this part of the valley. A few erratics on the east side of the lake valley, at the north end, but no till seen or probably here. Plenty of the old quartzite gravel in places on this spur between Hayden Lake and Rathdrum Prairie.

The terraces along the north side of the valley at Rathdrum and thence westward are all composed of stream gravel, so far as sections and soils show. The one at Rathdrum and reaching northward to the gashed notch two miles north of Rathdrum is 240 feet above the town or 2445 ft. A.T. It has an undulating surface that suggests ground moraine but no really undrained depressions. Its steep frontal slope is notched by several small steep-walled ravines, otherwise its surface shows no marks of erosion. A section 30 to 40 feet below the summit shows well-sorted, stratified stream gravel, mostly horizontal but with slightly inclined current bedding also. This gravel is not well worn, and is prevailingly fine. Erratic pebbles are abundant. No trace of erratic material was found above the terrace top.

The first terrace west of town is also 240 feet above Rathdrum. It has a definite marginal ridge, making of its surface an enclosed depression, now drained by a narrow valley. (p2c)

The next terrace down the valley is the one previously described, containing a marsh. Its barrier ridge is about 40 feet lower than the other two, at least where the road crosses it. Some of its exposed gravel on the frontal slope is current bedded.

The next terrace westward is mapped without a marsh but has a ~~sha~~ shallow basin, nevertheless, which is green and apparently very poorly drained. There is, therefore, here a situation similar to the other two. The surface here is 2400 A.T.

Neither Sucker (Hauser) nor Newman lakes are confined by such high barriers as the foregoing terraces constitute, or as Liberty Lake possesses. The barrier at the mouth of Sucker Lake is a very definite ridge 60 feet above the Wisconsin channel floor and nearly that high above the lake surface. The back slope of this bar is somewhat crenulate, while the front slope is uniform. Newman Lake has only a very low barrier ridge. Both of these lakes lie in rather capacious valleys. If Newman Lake valley were ponded to the foot of the hills about it, as is Hayden, it would be equally large. Its drainage area is two thirds or threefourths as large as that of Hayden.

Neither of these lakes has the high barrier. This may be because one was never built (a curious thing when these features are found both east and west along the valley wall), or because the barrier have been removed by erosion. The latter may be the correct explanation for Sucker Lake does possess a spur on the west side of its ~~va~~ valley mouth, a spur thatlooks like a remnant of the high feature.

Yet it is true that if they are bars, they might not be present built completely across in all valley mouths. Plenty of variants are known among the true channel bars of the scabland. Both Newman and Sucker lakes have fairly large drainage areas and it might be argued that post-Spokane, pre-Wisconsin erosion by their streams could clean out their Spokane deposits, or in thecase of Sucker, partially clean them out.

Newman Lake to Peone Prairie to Pleasant Prairie
July 23 I929

There are erratics on the west side of Newman Lake up to about 2580. Very few and probably berg-floated in Lake Spokane.

Two foreign pebbles (one four inches in diameter) close to the summit of the divide between Peone and Newman valleys and on the west side. Altitude a little above 2700. At 2660, erratics are abundant and thence down to the level of Pleasant Prairie. 2660 has a fine collection, including several boulders. Fragments all fresh, some very well striated, granodiorite porphyry present in two pieces in different places. This erratic material is too high for Lake Spokane and is a continuous fragmentary mantle down to the till-covered Pleasant Prairie. It therefore records the Spokane ice of Little Spokane Valley, here nearly crossing the divide to enter Newman Valley. The presence of the granodiorite here and also in a large pit half a mile south of B.M. 2431 (east end of Pleasant Prairie) shows that it travelled as drift in the Little Spokane lobe.

The mature topography of the east part of this prairie is older than Spokane. Most cuts show a deep residual soil under the erratic deposit.

The pit above noted shows poorly sorted bouldery debris, apparently a till that has been worked over somewhat by glacial water. Foresets dip southward , toward Spokane Valley. Abundance of striated surfaces shows that this material did not travel far from its release by the ice.

Pleasant Prairie and Spokane Valley July 23

The gravel that was spilled over the basalt brink at the east end of this little plateau into Spokane Valley did not form any delta-topped deposit above 2140 A.T. At that level, there is a marked terrace, noted in earlier years, but it may as well belong to the Spokane Valley system as to the minor spill off the prairie. Its volume seems too great for derivation from the north. A fine section in it shows well-sorted fine gravel and coarse sand without delta foresets, tho with current bedding.

A survey of the Spokane Valley, after descending to its floor, shows this terrace at 2140 to belong clearly to the group we have been tracing westward from Rathdrum. Another remnant is in the mouth of the capacious valley immediately west of Newman Lake valley and opposite Otis Orchards NP station. This valley has remnants on both sides at 2140, the same altitude just noted. Apparently, there was once a complete fill across the mouth and a marsh or lake farther back but the high edge has been trenched and a stream valley developed. Most of the flattish tract back in this valley, nearly 100 feet above Otis Orchards, appears to be the original fill and its consequent upvalley accumulation immediately after deposition.

But there is also a definite bar ridge in front of this partially dissected fill, a ridge with a very smmoth, slightly curving steep front with a narrow gash across it where the stream escapes and with a different aspect to its gravel. The older fill is composed of fine

gravel, largely horizontally bedded, well-sorted but poorly worn, while the bar (or at least its upper part) is composed of noticeably coarser gravel, well worn, with foresets dipping back into the trib. valley from the main. The bar summit descends about 25 feet back toward the flat, where the surface rises into the remnants of the older gravel to be 10 to 20 feet higher than the bar. No good sections, properly located, to show the depth of staining. The older gravel has 3 to 5 feet of dust or alluvium on it in one section, the bar has gravel to the grass roots.

This descending series of terrace remnants along the north side of Spokane Valley, from Rathdrum to Spokane, seems ~~to show~~ clearly to include the broad fill of Lidgerwood terrace, whose altitude and height above the Wisconsin valley train are right for such classification.

Two different views of their origin as terrace remnants are possible, both based on the idea that they ~~are~~ belong to the episode of glaciation recorded by the Rathdrum Prairie ground moraine.

I- They are remnants of a complete valley train reaching to and past Spokane. The test for this will be the continuation of the series farther northwest, down the Spokane.

2- They are bars built back in re-entrants by the Spokane Flood.

Under the first view, the removal of almost all the material, leaving only these small remnants, largely undissected by runoff from the higher slopes above them, could be ascribed to the Spokane Flood. This puts the flood after, or during the later stages of, the Rathdrum Prairie ground moraine glaciation. It makes it necessary to keep the prairie and the Post Falls T.M. covered with ice during the flood in order to preserve the morainic topography. It leaves the origin of the scabland basalt bench, just west of Coeur D'Alene city, out of the flood record, for this scabland is older than the moraine which occupies its channels. It requires the removal of a very great amt. of debris by way of the scabland channels, a feat requiring a hoist of 300 feet just west of Spokane. It seems impossible.

Yet if the valley train it represents is the same age as the Rathdrum Prairie ground moraine, the moraine is undissected while the valley train is almost wholly gone. This seems impossible except by the flood crossing ice on the Rathdrum Prairie ground moraine.

The second suggestion, that the remnants are really bars, has the following items in its favor.

A- It explains the higher outer edge of most of them.

B- It relieves one of the difficulty of bottom gradients, in respect to the 2450 floor of the scabland spillways.

C- It explains the lack of trenching of several by the runoff of the tributary valleys in which they lie.

~~But this second suggestion ignores the descending gradient of the group, it does not account for their fineness of material and uniform stratification, it requires ice over the~~

D- It makes the gravel deposits along the south side, which seem clearly to be constructional bars, a part of the same series and thus harmonizes the otherwise aberrant feature of great bars along one side, without valley train remnants and of high terraces along the other side without any associated bars.

But this second suggestion ignores the descending gradient of the group, it does not account for their fineness of material and uniform stratification, it requires ice over the Rathdrum Prairie ground moraine to protect that topography.

Perhaps a different assumption should be used to start with. Suppose that the Rathdrum Prairie ground moraine is younger than these terraces. Then the idea that ice occupied its site at the time of

the Spokane Flood is not needed, the contrast in dissection of ground moraine and valley train is explained, the moraine in the scabland channels west of Coeur D'Alene city is explained (for the Rathdrum Prairie ground moraine becomes post-flood). But the Rathdrum Prairie ground moraine is left without associated outwash unless it is in the rather unsystematic lower terraces along the Wisconsin channel, terraces that are better explained probably as Wisconsin affairs themselve

The view that these remnants are bars can readily by checked by study of the Spokane Valley below the city. If present, they emphatically are not bars.

The Wisconsin valley train rather clearly begins on the west edge of the Rathdrum ~~Prairie~~ sheet. At Trent Station, it extends from the river (or a little south of it) completely across to the north wall of the valley. In Spokane, it extends from the Lidgerwood terrace south to the basalt slopes south of the business district.

I have been anticipating gravel terrace flats, deltas or what you will, related to the Spokane till of Pleasant Prairie, Five-Mile Prairie and other similar ~~feature~~ tracts, at 2450 or somewhat higher. Should I? If the episode was a sudden and mighty flooding from a localized source, the general ice edge had too slow a melting rate to build any deltas or valley trains adjusted to the scabland channels. If such features do exist, they mean normal glacial lake water back of the channel heads. If they do not exist, the discharge to and thru the channel heads must have been short-lived. Yet if the Spokane drift is younger than the channeled scabland (vide the moraine north of ~~Medical or Silver~~ Willow- Granite Lake) this criterion is unusable.

Spokane Valley July 24 1929

The Lidgerwood terrace is rather definitely a part of the system of fragments from Rathdrum down the valley. It is the highest terrace in the valley here, as are they where they occur, its altitude being 2095 close to the southeast corner of Five-Mile Prairie. Its bedding is foreset in many places, the foresets dipping variously but, nearer the cliffs of Five-Mile Prairie, clearly and definitely toward the cliff. Here also the surface descends 55 feet into a pronounced fosse which separates the terrace fill from the plateau outlier. The bottom of the fosse descends northward along the entire east side of Five-Mile Prairie cliffs.

Lidgerwood terrace extends north to the mid-valley basalt hill 2 miles east of Dartford. It descends about 200 feet (perhaps 250 ft) in five miles northward. This, with the north-dipping foresets, indicates northward flow of the water which made it. The surface near the mid-valley basalt hill is the same altitude as the high gravel terrace northward along the east side of the Little Spokane valley as far at least as Chattaroy. It is all Spokane in age, related to the Spokane till about Diamond Lake, Eloika Lake, etc., Therefore the Lidgerwood and all the fragments up to Rathdrum are Spokane. The surface of the Lidgerwood is diversified by a belt of sand dunes which extend diagonally across from the south end of Five-Mile to Mead. Maximum relief of the dunes observed is 140 feet. The average is perhaps 30 feet.

The terrace breaks off into two minor terraced benches at the north, descending to the Little Spokane. Total descent to the Wisconsin valley train in the vininity of Whitworth is 280 feet. The Wisconsin valley traine here is definitely marked off from the Lidgerwood gravel fill. There is no pobbibility of interpreting their contact as a grading of one into the other.

The Lidgerwood terrace is clearly continued westward around the south end of Five Mile Prairie, where its width is more than a mile. Its surface here also bears some duney tracts. It is 20 to 30 feet lower along the valleyward edge than next to the cliffs. From this portion of the high terrace south of Five Mile, the terrace is easily traceable northward along the west side of Five Mile as far as the Wisconsin valley train in the Little Spokane valley, at the north end of Five Mile. Its surface descends something like 80 feet in that distance but the descent from its northern terminus to the Little Spokane valley train is 240 feet.

The wooded slopes from Nine Mile Bridge, at the mouth of the Little Spokane, downstream for several miles conceal any remnants of the Lidgerwood (or Spokane age) valley train. A tributary valley fill at Tum Tum, almost undissected, is 1950 plus or minus, and 200 feet above the very definite Wisconsin valley train here. Still farther west, at the lower end of Long Lake pond in Spokane Valley the Wisconsin valley train is very marked indeed, with a fosse in places between it and the rock slopes. Here also appears to be a remnant of the Spokane valley train in a pronounced scarp of gravel to the north, which rises anyway 150 feet above the Wisconsin valley train. I must have some readings on this in earlier notes but I probably called this high gravel Wisconsin in age, thinking it to be outwash from the western arm of the bifurcation of the Springdale-Loon Lake lobe. If it is Spokane, where is the Wisconsin outwash from this lobe? Is it farther west than we went today? West of the power house and dam at the end of Long Lake?

Today's findings show that a vast valley train, probably Spokane in age, certainly pre-Wisconsin, once filled the Spokane and Little Spokane valleys and the empty valley between Pleasant Prairie and Five Mile Prairie. This valley train led down the Spokane Valley toward the Columbia and if its waters did not escape around the great bend of the Columbia they could only have escaped thru a Grand Coulee as deep, or nearly as deep, as the present. None of the gravel terraces ~~fou~~ found in Spokane Valley this season can be correlated with the channeled scabland discharge. They are all much too low and they have a definite gradient down the Spokane Valley, showing escape westward past the channel heads.

If the Rathdrum terrace remnants and the Lidgerwood terrace are parts of one valley train, it must have been built from ice on Rathdrum Prairie, presumably the ice which made the ground moraine there. If this be correct, then as that ice retreated, a valley train should have been constructed across the ground moraine here, just as it was across Spokane drift in the Little Spokane valley. The only part of the prairie which may record such valley train is what has this season been called the Wisconsin channel. This channel is terraced, the upper terrace being the broadest. Perhaps this should be the Spokane valley train of the retreating phases. But this highest terrace in the Wisconsin channel is lower than the high terrace just north of Rathdrum, so much lower that one must think that the closing phases of the Rathdrum Prairie ground moraine glaciation's discharge eroded away a good deal of the valley train built at the maximum of the glaciation.

Perhaps the Rathdrum Prairie ground moraine is a later glaciation after all. Perhaps the Rathdrum Prairie is not ground moraine but is hummocky outwash.

Prairies Northwest of Spokane July 25 1929

Morainic topography is as well developed on Indian Prairie as on Sunset Prairie to the south. In places, it probably excels. One of the most striking moraine ridges is south of the Indian Prairie road up from Spokane Valley, about midway between Great Northern School and White Bluff school. The ridge here is 70 feet above the lowest land to the north, and perhaps 50 feet above some undrained hollows to the south. It is good moraine, tho not kettly nor kamey. It is littered with basalt cobbles and boulders, plucked from ledges and low cliffs a little way to the north. A few erratic boulders. No sections seen.

This moraine ridge deposit is definitely related to the scabland cliffs and valley slopes that have been noted in previous seasons along the margin of Spokane River valley here. The relationship is a superposition of moraine on scabland. The only possible way of making the scabland equal to the moraine in age is to develop the scabland earlier in the same episode. Glacial plucking may have made this scabland but, if so, the debris was largely removed and a far smaller quantity was left in its place when the ice retreated. Another explanation, obviously, is that the scabland originally covered this part of the plateau, and that it has subsequently been largely buried by till, only a belt two or three miles wide being left along the Spokane bluff tops, showing thru the moraine cover. The presence in very many places of basalt outcrops thru the drift farther west on Indian Prairie give color to this view. So also does the relationship in the channel heads marked by the several lakes among the steptoes near Cheney. This will now be described.

The morainic sheet of drift on Sunset Prairie, previously examined in 1927, has a fairly definite marginal ridge, down from which it descends to scabland rock surfaces in all of the channel heads. The ridge probably is nowhere more than 40 feet above this scabland and its southern slope is gentle. But moraine certainly does come very close to these channel heads and in one place (Willow Lake-Granite Lake it is pushed completely into the channel head, descending to Willow Lake itself. There is no doubt about closure here, there is no possibility of lateral entrance of channel-making waters here.

Either the water that passed thru these spillways came directly off the ice then resting on the moraines or the channels are pre-moraine. In the first case, it seems impossible to get the quantity of water required from the narrow ice fronts involved, unlikely that the rock basin lakes, even if formed, would remain unfilled by outwash of the closing stages. In the second case, the objection of outwash filling them holds equally well. In other words, there is no explanation for the survival of the lake basins, even if an explanation of their origin can be constructed.

The highest erratic seen along the road north of Hite is about a mile and a half from the station and 2580 A.T. This is higher than any other ever before found in this district.

The Marshall "delta" is the edge of an outwash plain lying in front of the Sunset Prairie moraine and spilling over in fine foresets into the valley near Marshall. Altitude of its surface at the brink is 2287, much too low for discharge of its water thru the scabland channel to the south. Also it is much too high to be correlated with the Lidgerwood terrace. It is older than the Lidgerwood, having been built at or more nearly at the maximum stand of the Spokane ice. Its flat surface and abrupt termination indicates a deltaic origin. It never extended across the creek valley. Where was the outlet of this lake? Could it have been around northward thru one of the channels?

to the west and thence westward along the edge of the ice? Could it have been any other place?

A large fragment of the valley fill of Lidgerwood age lies in the canyon at the junction of Deep Creek and Coulee Creek. Its altitude is 2020.

Cheney, Brown's Butte and Latah Creek

July 26 1929

Granite scabland on the east side of the Granite Lake channel in a flattish topped shoulder up 60 feet above the lake. Rocky ledges go up higher on the steep scarp back of this shoulder, but are not clearly remnants of channel floor. A mid-channel butte 35 feet above the lake, on the north end of the lake.

Relation of moraine to scabland is no clearer than before. The moraine is surely up against the north foot of Brown's Butte where hillocks of debris stand 30 feet above undrained depressions adjacent to them. PLentifully sprinkled with a large variety of erratic boulders, several of which are well striated. But the steep slopes of the butte itself, just beyond the moraine, are soil-covered. No scabland to compare with the moraine. Around the west end of the Butte is the same situation except that definitely expressed moraine isnt present. To the southwest of the butte, the lower slopes are of loess and bear the loess topography for half a mile out from the hill. But on the south side is drift, perhaps moraine, in part; drift which has come in from theeast. Here also no relation of drift to scabland is decipherable.

What looks very much like ground moraine extends southwest from the butte to Paradise School. At the school, a gravel pit shows that outwash is present, probably no till. Thence southwest for about three miles, the yellow pine forest is growing on basalt scabland of weak expression but containing a number of old channels, now filled with sediment and organic matter. No evidence of moraine in here. A mile north of Dynamite, this scabland becomes nearly obliterated under drift and, tho there are no good morainic forms here, it seems best interpreted as moraine. The relief of the basalt under the drift and projecting thru it seems the same as that of the scabland south of Dynamite. The same question arises; is the scabland older than the drift or is it simply an earlier product of the same glaciation?

Morainic material and some morainic topography on the northern part of Paradise Prairie, on the big projection of high land between Marshall Creek and Latah Creek. Modified by wind-drifted sand in part but striated erratics and plenty of unstriated ones beneath the sand in some places cuts. Outwash also present up the slope from Marshall Creek about to the level of the Marshall delta. Apparently this valley, like Latah, was largely filled with outwash during the maximum and early retreatal stages of the Spokane glaciation, and has been re-excavated since.

In the middle of the Medical Lake channel, east of the south end of Clear Lake, is a small hill of argillite, condiderably higher than the uppermost ledges of basalt. To its lee is a small bar whose structure on the west side, shown in a gravel pit, is strikingly foreset, the dip being southward and eastward (out of the Clear Lake channel).

Fosses July 26 1929

A good fosse, 30 feet or more in depth, lies west of the terrace on which Ft. Wright stands. It is followed by the Great Northern RR. The fosse seems to be a feature, in many places, of the margin of valley trains in this region; valley trains both of Wisconsin and of Spokane age. The fosse is truly a bar feature and indicates the bar-like character and condition of this glacial river gravel. It is essentially the same thing as the back slope of a bar and, by this interpretation, the lakes blocked back of valley train deposits along Spokane Valley, are simply in very wide fosses, the widths being along the blocked tributary length. If this is a correct view, it may well be that the so-called great bars blocking Liberty Lake, Saltese Marsh and other valleys along the south side of Spokane Valley are bars only in their back slope, the frontal or valley-ward slope being erosional just as are the valley-ward slopes of the terrace fragments from Rathdrum westward.

The merit of this view is that it gives the high gravel, the Spokane gravel, of both sides of the valley, the same character; i.e. remnants of a valley train. Otherwise, there is a most inharmonious interpretation of the two sides of the valley. The bar interpretation was made for two reasons. The magnitude of the back slope (the fosse slope) was such that it seemed necessary. The frontal slopes are not strikingly scarped and appear as truly constructional as the back slopes. Furthermore, bars were rather expected here, by the flood hypothesis. Since, however, these so-called bars are far too low for the Spokane Flood, this apparent need disappears and the intepretation can be made without preconceived ideas of what should be there.

The fosse affords another means of interpreting the lower terrace below the main Wisconsin valley train level. If they are only erosional terraces, then where they come against higher slopes there should be no fosse. The Fort Wright terrace was thought, at the time of passing, to be the same as the railroad terrace in Spokane and erosional in origin. If it possesses a fosse, it must be depositional and therefore the original surface of a valley train. Better see the Fort Wright terrace again.

Latah Valley July 26 1929

The sediments exposed in cuts along the Inland Empire Hiway between Brown's Butte and Spokane conform to the generalization proposed on July 18. They are coarser farther north, finer farther south. But the cuts do not extend far enough south to expose the dominant silty phase.

Beginning with the great gravel deposits along the NPRR, on the east side of Latah Creek Valley, the cuts show mostly sand and silt where the hiway begins to climb out toward the south. Here there is a grade of about 5% about half way up to the plateau level, then a stretch on a rude and irregular terrace, then another length of steep grade to emerge from the canyon. The cuts in the upper length of steep grade are all in loose sand, so far as seen. In the lower stretch, sand alternates with silt. This is a departure from the generalization, perhaps one that indicates the mid-depth terrace to be a later deposit made under somewhat different conditions.

The alternation of sand and silt in the lower cuts presents some of the most intricate intraformational corrugations in the silt I have ever seen. One of the most surprising things is the presence of secondary corrugations on the primary ones, and in some places, even tertiary corrugations on the secondary. These minor ones are of very minute dimensions and require very good laminations to show it.

Thickening and thinning on the corrugations are well shown
The associated sand layers are all current bedded and the shallow foresets all dip southward. These sand layers, except locally, are undisturbed by the crumplings which are very diverse in shape, location and magnitude in the successive layers. It is clear that the settling which made the crumpling occurred during deposition and ceased by the time the sand above each crumpled layer was being deposited.

Where did the water flow which made these current foresets? It couldnt flow out to the south at any altitude comparable to that at ~~wh~~ which the strata occur. Yet the southward flow is indubitably recorded? Nor is the gravel along the NPRR cuts foreset as delta gravel should be. Perhaps this cut should be seen again. But could bottom currents, in 2000 feet or so of water, make these current foresets? Would not deltaic foresets be inevitable? It seems at present that only a very great volume of southward-flowing water could do this at such depths, and this debars any of the fine sandy silt from settling, as it surely did settle. Is there here another record of pauses in the flood discharge? Why did the pond fill up or so nearly fill up, if a great flood discharge is here recorded? Isnt it much more probable than most or all of this silt and sand was deposited in a back water of the Lidgerwood (and perhaps also of the Wisconsin V.T.) valley fill in the main valley? If so, then there is no record in Latah Valley of the Spokane Flood.

Traverse from Spokane to Coulee July 27 1929

Much of the moraine on Sunset Prairie, where cut in road sections, is very gravelly and rather uniform in size of fragments. It looks more like outwash than till. Probably a great deal of water action across the ground moraine. As ground moraine, it is about like Rathdrum G.M. in general, tho it also has more marked morainic hills here and there. That much outwash was deposited here is shown by the heavy sand deposit along the steep grade down to Deep Creek from the east along the hiway. But on the lower land west of the creek, the topography is again ground moraine. It is difficult to get this sand up on this slope unless the lower land to the west and northwest was ice-covered to protect the ground moraine. Perhaps this higher ~~tr~~ tract east and southeast of Deep Creek is largely a morainic accumulation.

Reardan. The northern bar is considerably the smaller bar.

Wilbur. Bar north of town has excellent foresets of very poorly washed and almost unworn basalt gravel dipping northward from the channel. In one place, a patch of loess still remains under the foreset gravel.

Almira. Excellent bars, four or five of them, in the channel leading southward toward the Wilson Creek route. Photographs of one banked up against scabland basalt valley wall. The relationship here is identical with that of moraine banked up against scabland on Sunset Prairie, except that in this case the agent which made the scabland also made the bars when in different phase, while on Sunset, it is not clear that the ice made the scabland. Upper limit of scabland on south side of Wilson Creek channel along gravel road which climbs out above the stream forks is 2010. Erratics lie on the loess 30 feet higher. Also basalt fragments which are fresh riven pieces. Depth of Wilson Creek ~~channel~~ river here is 350 feet, a very surprising figure.

Hartline. The triangulation station on the summit three and a half miles north of Hartline is 2580. The surface of the uplifted tract drops 130 feet in about a mile to the north of this station, ~~beyo~~

Isn't it more probable that the buried rock basin here referred to is a plunge-pool basin, elongated by cataract recession along upper Grand Coulee? The cataract, if such ever existed, took origin where the monoclinal structure crosses the coulee, and the basin now begins at the same place.

beyond which the surface evens out on the plateau. There is, therefore, a minor anticlinal pucker here. Highest erratics 8 miles directly north of Hartline are 2400. Highest scabland on Spring Coulee walls, almost overlooking the Columbia on extreme east edge of uppermost Grand Coulee scabland, is 2382A.T. Altitude of the old schoolhouse (Columbia District) at head of Grand Coulee is I530, according to Major Hopkins, U.S.Army Engineer.

Grand Coulee July 29 I929

The silt deposit of upper Grand Coulee has its greatest undissected remnnnts within 5 miles or so of Coulee City, just north of the rugged scabland that characterizes the floor at Coulee City. The flow in which this extreme basin, channel and butte topography is so well developed dips northward at a low angle, with all the other flows of course, and this dip carries the scabland-maker below the channel floor. But with this goes all basalt, so far as surface exposures are concerned. Apparently, the overlying basalt flows, or few flows, yielded readily and left no remnants. They yielded so readily that there are actually exists a major rock basin for several miles above Coulee City, filled with silt and its downstream rim consisting of the rugged buttes and basins that extend thence to the brink of the falls.

The large irrigated orchard above Coulee City lies on the silt terrace and for at least two miles farther north, the terrace is the dominant feature of the floor. It has very few gullies here but is limited to the eastern half of the floor, the western half being occupied by a broad channel containing also a silt floor and several very shallow alkaline basins. The orchard proprietors pump water from the level of the flat 80 feet to the orchard on the terrace. The total relief appears to be 90 feet. And this is apparently all silt. Nothing else shows in the slope between terrace and channel.

A few miles farther north, the silt deposit on the east side of th valley is much dissected and has no flat-topt remnants. Here its height above Alkali Lake flat is 75 feet. And in one place, it has been removed completely to the foot of the east wall of the coulee.

Farther north along Grand Coulee, the silt exists chiefly in dissected forms and it looks as tho local rainfall had been responsible for its removal. But if one considers that the main channel thru the coulee is nearly a mile wide and nearly I00 feet deep, yet has almost no gradient and has a number of shallow, broad basins, it seems clear that a river current thru the coulee subsequent to the deposition of the silt is necessary to explain this channel.

The silt upper surface is I570 feet AT. Must work out its relation to the scabland surface about Coulee City. Is this surface high enough to form a dam to determine this upper surface of the silt? If not, why is this silt here with this level top and yet known nowhere below the falls? The silt is varve-bedded and very fine textured, making a dense hard blocky surface when dry. Yet no pebbles or other fragments, drops from floating bergs, have been found in it. A glacial water pond which received I00 feet of rock flour and yet had no bergs in it! What explanation?

Beneath the silt in one place is a great accumulation of huge boulders, many of them 4 to 5 feet in diameter and all well worn. About midway between Coulee City and Steamboat Rock, this bouldery substratum has lost its silt cover and the surface along a belt parallel with the coulee walls is strewn with even greater frgments of granite and basalt. This is I2 miles from Coulee City. Some basalt fragments are 20 feet high. These appear much too huge for any stream transportation along the low gradient and they raise the sugges—

tion that this is a part of a moraine, left by an extension of the ice which rode over Steamboat Rock.

A splendid bar lies back in an alcove or short wide tributary gorge entering Grand Coulee from the east, 9 miles north of Coulee City. Its summit is 163 feet above the channel floor and more than 60 feet above nearby remnants of the silt which lap up on the bar ~~slo~~ slopes. The bar summit is in the middle of the alcove, about 30 or 40 feet above the contact of bar and south wall, and 85 feet above the bottom of the fosse on the back side. Along the north side, the bar has steep constructional slopes almost down to contact with the basalt cliffs. 20 to 40 feet of erosion has been done here by drainage escaping from the fosse.

The material of the bar is of well-sorted, fairly well rounded coarse gravel. No boulders and almost no cobbles seen. 99% plus is basalt. Structure on the west slope, facing Grand Coulee, is ~~current-deltaic-foreset,-the-dip-in-exactly-the-opposite-direction-to the-course-of-the-Grand-Coulee-glacial-river.------Here-is-an-eddy-bar~~ current foreset with dip southward, down the old coulee. Structure on the east slope, facing the fosse, is deltaic foreset, the dip in exactly the opposite direction. Here is an eddy bar in every particular needed. It is older than the silt, it requires a glacial river considerably deeper than it is high for its making. It may date from the same river that left the huge boulders beneath the silt. It post-dates the erosion of the alcove or short gorge tributary. It therefore post-dates the making of upper Grand Coulee in its present proportions, and thus is much younger than the high scabland above the east wall. If this oldest scabland is to be called Spokane in age, the bar is post-Spokane. Is it Wisconsin? Was there ever such a Wisconsin discharge thru here? If the Spokane Flood preceded the glaciation called Spokane, this bar might date from that glaciation.

Lower Grand Coulee was viewed this afternoon from several salient points on the high western rim. Never have I seen scabland so amazingly portrayed. It is nearer an aeroplane view than even the Saddle Mt. view of Drumheller Channels. The view ranges from Dry Falls to Soap Lake and well out onto the south rim of Hartline Basin.

Tho not all details can be made out, several of the previously identified features were seen and some new ones. The hill south of Bacon, locally called Pinto Ridge, fuses with High Hill (the loess-covered hill west of Pinto Ridge) in the view. Dry Coulee thus does not show, except from more northern salients. Nor does Spring Coulee east of Pinto Ridge. But Lenore Canyon is a particularly prominent feature for some distance over toward Dry Coulee. And another canyon-coulee, a mile or so north of Lenore Canyon, is also conspicuous It joins Grand Coulee in the same great embayment, deeply gravel-filled, that also contains the head of Lenore Canyon. It appears to lead eastward in the same way and probably is the deep canyon previously mapt across here north of Lenore.

The very extensive gravel-filled area east of the foot of Blue Lake and head of Lake Lenore (Alkali Lake) extends back toward the east for about two miles. It has relatively low basalt cliffs definitely marking out the limits of the gravel. There are also no scabland buttes or knobs interrupting it. Its surface is rolling and drops off abruptly in a 200 and 265 foot descent (two crest lines) to the floor of Grand Coulee.

The transverse canyon north of and similar to Lenore is called Jasper Canyon by McCann. Near its junction with Lenore, about a mile back from Grand Coulee proper, there is a canyon notch, equally deep and wide, across to the head of Blue Lake, thus making a great scabland butte here on the east wall of Blue Lake. It also is deeply gravel-

filled, the gravel disposed wholly in bars.

But the most surprising thing discovered from these viewpoints is the existence of a definite broad scabland channel east of and essentially parallel to Grand Coulee channel where occupied by Lake Lenore, and separated from it by a very narrow, very long and very shapp ridge. The ridge is steeply cliffed down to the floor of both channels. A part of the ridge, the southernmost, is considerably higher and is a blade very like that in front of Dry Falls. The floor of the newly discovered channel is strongly marked by butte and basin ~~topography~~ and channel topography of the type developed in the surface flow above Dry Falls, a type without great relief in a flow made up of small columns.

It looks from the summits, a thousand feet above Grand Coulee, as ~~if~~ tho these two channels, with their separating ridge, were the product of twin waterfall recession, like the Dry Falls blade and the Potholes blade. This interpretation would require that somewhere near the foot of Blue Lake, the western fall obtained the ascendancy and deprived the eastern channel of its share of the water. Subsequent to this, deepening in the western or present channel has left this parallel channel hanging high above the lakes. The head of the new channel is not marked by cascades or cataract; it rises irregularly until it is essentially at the level of the top of the cliffs bounding Lenore Canyon on the south at the junction with the wide, gravel-filled embayment or lateral canyon. Lenore Canyon apparently had not been excavated to any extent at that time. Indeed, it could not be excavated until the main canyon (Alkali Lake or Lenore Lake) had been cut, itself subsequent to the victory of the western over the eastern spillway.

July 30

An examination in this tract, above described, shows that the bar slope descending to Alkali (Lenore) Lake from the big gravel fill is 200 feet high, that another bar 65 feet higher lies a little farther back and a third, 330 feet above the lake, lies against the south slope of the isolated basalt eminence east of Blue Lake. The basalt high scabland of this eminence here is 450 feet above the lake.

The examination also shows that the bar in the short transverse canyon between Jasper and the head of Blue Lake is 150 feet above the lake and has a 35-foot fosse on each side to isolate the rounded summit out in the canyon. East of this bar is a wonderful profusion of bar forms in every conceivable position, many of them 100 to 150 feet higher than the one just noted. A fosse back among these bars descends 50 feet below its lowest surroundings, the top of the bar close to the lake.

Lenore Canyon is simply clogged with bars. There is no channel thru among them, there is simply a succession of undrained fosse depressions. The most pronounced of these is 135 feet deep below the enclosing gravel bars and its steepest slopes are 40 degrees. Almost no erosion has occurred on these magnificent constructional forms.

Lower Grand Coulee July 29

The newly discovered channel east of Alkali Lake was entered and traversed. The prominent blade of rock at the south tip of the long spur or ridge separating the two channels is a very spectacular feature, about 300 feet above the eastern channel floor. It is very narrow east and west and almost unscalable. The flow which constitutes its long summit (a central higher ridge stands on that, in turn) is made of huge columns 4 feet or so in diameter. These constitute the wall that makes climbing difficult. The columns are 15 to 20 feet long.

The floor of the eastern channel is marked by holes, channels and buttes in profusion. Many of the holes are undoubtedly plunge pools.

They even have overhanging sides in places and are sharply circumscribed and not interpretable as channel ~~forms~~ basins. This floor has a conspicuous upstream dip which amounts to perhaps 50 feet to the mile Nevertheless, the development of scabland forms on it is marked almost thruout. In one place, the basalt is cut by north-south joints, long ones like those in a sedimentary rock and the basins have been plucked along them, making them elongate at an angle of 40 degree or so with the channel length.

This upstream dip is a curious thing. It makes difficult the interpretation of the channel floor as such unless one has an enormous volume of water to use.

The downstream edge of this flow, where it is highest, is high ~~ab~~ above Alkali Lake on the west. It appears itself to have determined a cascade or cataract there. This high edge is cut by a channel that was developed as the northern and lower part of the dipping floor was cleaned off of overlying flows and sculptured into scabland forms. This notch explains in part the erosion of the upstream lower part of the flow.

Four miles or so upstream from the high edge transverse to the ~~ch~~ channel is a waterfall cliff completely across the channel, composed of long columns of the next higher flow, now removed farther downstream along the channel floor. A large rock basin lies at the base. Height of the fall is 50 to 75 feet at least. The brink of this wide fall is as low as the floor of the incised smaller channel in the down stream edge of the dipping flow. How could a waterfall develop under such conditions? Only by the waterfall being entirely subfluvial. This situation demands a great volume of water.

The eastern channel, north of the waterfall, rises rather steeply over the edges of several flows, marked by irregular cascades, rock basins and channels. One rock basin holds a lake, (Bluff Lake), rimmed on the downstream edge by a sheer and even overhanging rock cliff 20 feet high. Still farther north, the channel loses its unity and becomes a series of anastomosing smaller irregular channels, separated by numerous buttes. Channels are at various levels also. These features continue right up to the brink of the cliffs overlooking the great bar-filled embayment at the head of Lenore Canyon. It is as high here as the summit of the scabland butte east of Blue Lake.

It is obvious that when this eastern channel was in operation, there was no deep western channel where the lakes now lie and there was no Lenore Canyon. The eastern channel is one of the earliest features of glacial water discharge thru the Grand Coulee route, its floor at the head at least 500 feet above the floor left under the lake.

A remarkable feature of this eastern channel is the almost total, or total, absence of bars. The view from the head, on the brink of the south wall of Lenore, is almost startling in the contrast to the north and the south. Bars choke the canyoned channels to the north, rising almost as high as the head of the eastern channel on the south slopes of the broad butte east of Blue Lake (tho descending 300 feet or so across the embayment to the foot of the south wall of Lenore) And not a bar in the high eastern channel!

The interpretation clearly calls for a notable change in conditions between the abandonment of the high and low channels. Why any channels such as these should not have bars deposited in the closing stages of glacial discharge is difficult to explain. A perfectly normal thing is to accumulate bars on the channel floors at such time. Such channel bars could not form while the channel was being eroded. And to explain the absence of bars in the high channel requires only that during the erosional phase of maximum discharge, the 500 feet of deepening

occurred, drawing off the water rather abruptly and diverting the traction load of gravel elsewhere in the deeper channels. This argument is obviously an application of the flood hypothesis. The bars of channeled scabland, where lying in channels, are the last phase of the extraordinary episode.

Another feature of great significance is the existence of the two parallel channels for several miles. Twin gorges like these, with a stream-swept, greatly eroded yet very sharp definite divide between are unknown outside of scabland. Even here they need special explanation. The clue is to be found probably in the remains of preglacial tributary valleys on both east and west of the double channel.

On the east, two short but flaring trib valleys enter from the west slope of High Hill, joining the eastern channel essentially with accordant grade, showing that this channel floor was not greatly deepened by the glacial stream. Yet these tributaries could not flow to the western deeper channel directly, for the long narrow bare rock divide rises in the way.

The preglacial tributaries now entering Grand Coulee from the west hang several hundred feet above the lake surface. If their present gradients be projected eastward, they will just about cross the summit of the divide separating the two channels. The pronounced blade ~~s/h~~ should represent the location of a shoulder between two ravines from the west. Since each channel is nearly a mile wide (?), it may be assumed ~~that~~ without hesitation that the original width of the preglacial drainage way here has been notably increased by the glacial water. This widening of the preglacial route on its western edge would produce the hang that exists here below the projected profile of the western tributaries.

Assume, now, that the western and deeper channel marks the preglacial route. The eastern tributaries then must detour to the south to enter it, not an impossibility, but the preglacial floor must be very much higher in order to fit in with the profiles of the western tribs. This, however, is going to be far too high for the preglacial tribs. from the east. The preglacial route, therefore, is the eastern one.

The eastern route is developed in the nearly horizontal strata immediately east of the monocline. The divide in some places shows the last of the dipping beds as they turn into a horizontal position. To the east, the flows pass into a gentle incline upward eastward. The preglacial route, therefore, is in a shallow syncline here at the foot of the big monocline.

But the great channel of Grand Coulee is eroded in the dipping beds. In most places, mid-channel ~~butte~~ low buttes, chiefly as islands in the lakes, bear te only dipping beds, the flows on both ~~sid~~ sides being horizontal in section. If the shifting of local drainage here during the diastrophism located the preglacial course, it logically should be in the bottom of the downfold. This is where the eastern channel is located. If, now, glacial water should be spilled over ~~into~~ the divide from the north, it would follow the bottom of this structural-~~valley~~-- erosional valley and would alter this by deepening and widening. The widening might be more on one side than the other because dipping beds and horizontal beds probably would differ in response to erosive attack of a large glacial river. But production of the very much deeper lake-filled gorge in the tilted beds cannot be a product of such lateral shifting for the high sharp bare rock divide stands between.

The implications are obvious. There is no logical way to explain this deep main channel of Grand Coulee alongside, but separated from the preglacial course, except by using the enormous volumes that the ~~fl~~ flood hypothesis calls for. Then, with great velocity, and plucking

ability up on the western slope of the preglacial course, the tearing out of the broken and flexed basalt would begin and would proceed until eventually the main course would be shifted over here and the original course might even be abandoned (see absence of bars).

This procedure seems a bit fantastic, perhaps, even when dealing with a glacial river of such extraordinary volume and vigor. But the only really difficult feature to explain is the middledivide between the two channels. It should have been torn away while the western channel was developing.

Yet this hypothesis must be in error for its demands for rapidity of erosion are impossible. The great volume demanded can not be maintained indefinitely, a few years at the most seems all that can be granted. And if the episode isnt repeated, with similar volume, all this attack on and removal of the flexed belt must occur during this short time.

A bit of evidence on the yielding of basalt is found in the thousands of huge "haystack" rocks on the moraine northwest of Coulee City. They are so tremendous, compared with boulders of any other kind of rock in the drift, that some explanation seems necessary. Of course they are locally derived but this does not explain size, it simply explains why the original great size has not been decreased by glacial transportation. In the Colville reservation north of the Columbia, the drift in the granite country does not have excessively large granites, tho it may be mostly of granite.

The answer in part is that these huge basalt boulders were taken from the peculiarly favorably located ledges that face northward along the edge of the plateau. But similar ice-facing cliffs of rock are common enough, yet no moraine that I have ever seen has such boulders of any kind of rock.

A second factor seems indicated and that is the facility with which basalt yields under plucking stresses. The plucking seems to have been possible where the north-facing cliffs could receive a partial lifting movement of the ice up from the Columbia Valley, or where south-facing cliffs (there are a few of them) had ice across the top from the north.

Most of the ice-worn surfaces of basalt seen are greatly smoothed and show no plucking out of such surface, i.e. no pitting by removal of columns or parts of columns. Ice, unlike stream water, does not lift blocks up into itself in plucking operations.

Channeled Scabland within the Glaciated Area west of Grand Coulee.

The Wisconsin Okanogan lobe left such extensive drift deposits that the bedrock topographic details are largely concealed. In some areas, however, the outcropping basalt is prominent. It seems to owe its prominence to an unusual roughness of its own surface, so great that its relief is greater than the thickness of the drift.

In such places, the character of the bedrock topography can be deciphered. It consists of knobs and buttes and hills of basalt, isolated and irregularly grouped with reference to the depressions separating them. The depressions being continuous, tho themselves very irregular, can not be interpreted as preglacial stream valleys (except greatly modified ones). These features with their overlying morainic deposits and topography, look just like those on Sunset Prairie. Either ice erosion or glacial stream erosion has given them the scabland topographic features. If ice erosion were responsible, these features should be present thruout the glaciated area, at least where basalt is near the surface. But they are limited , so far as

observation has gone, to two tracts; a belt two to five miles wide along the west edge of Grand Coulee, and the region about Grimes Lake, the northern lake of Moses Coulee. Especially in this region do these hills and depressions in basalt look like modified channeled scabland.

The head of Moses Coulee is just north of Grimes Lake. It is a an abrupt termination, walled by 100-foot cliffs, identical with the features of channeled scabland which are called abandoned cataracts. The basalt above these walls has been strongly glaciated, tho now obscured somewhat by weathering. A narrow gorge has been cut subsequently into this cliff by drainage from the north across it. Perhaps Wisconsin glacial drainage did most, but post-glacial drainage has done some of it.

The top of the basalt walls is the irregular floor of several modified preglacial tributaries which concentrated approximately at this place. Gathering of glacial water into Moses Coulee over a width east and west several times that of the coulee seems recorded. This water could easily come across the plateau from the north at altitudes lower than 2500. Mansfield is 2267 and few of the hills to the east for several miles are higher than 2300 while most of the sags are less than 2250. Good evidence for channeled scabland in the latitude of Mansfield was not found. The divide between Foster Creek drainage and Moses Coulee drainage is hardly a mile north of the latitude of Mansfield. My former impression of a wide high plateau, with the coulee heading down on the south slope, is erroneous. It is possible that glacial flood waters entering the early Grand Coulee route might have been nearly continuous over the northern part of the plateau, and even over the divide with those entering Moses Coulee. Lake Missoula may have been the source of water thru Moses Coulee just as well as it could have supplied any other channels.

A final question, yet to be answered, is why Douglas Coulee escaped the drenching. The answer must be that the plateau to the north and east (separating it from Foster Creek and Moses Coulee) was too high. There are no marked elevations in sight but the RR altitudes show Touhey as 2361, Withrow as 2515, Supplee and Douglas 2282. This shows a rise of more than 200 feet from Mansfield to Withrow, toward the southwest. Withrow is almost as high as the uppermost erratics of the channels near Spokane and higher than any of the channel floors. Here must have been the high land that prevented the Spokane flood waters from spilling into Douglas. Logically, these waters, if from Lake Missoula, should have had a surface gradient descending westward and 2300 or 2400 may have been the upper limit here. A tract of considerably higher land lies north of Withrow and between Mansfield and Waco. This, however, does not entirely block the glacial drainage from Douglas Coulee.

A drainage line rather deeply incised leads eastward thru Silco to Moses Coulee just south of the moraine. It is a preglacial trib. of Moses Coulee. No scabland forms seen. Drift on the north of this valley, Palouse loess on south. It should hang, or be sharply trenched, at the junction with Moses.

Spokane icesheet margin approximate location will have to be shifted. It must have gotten nearly as far south as Withrow. Must it?

Moses Coulee August I

Scabland knobs, buttes and channelings are marked up on the west bluff of Moses Coulee along the Sunset Hiway higher than // 300 feet. They ~~never~~ occur on a shoulder between a small trib and the main coulee, a sholder which was clearly overrun by the great volume. Another trib. entering just to the southwest did not recieve the overpour and has perfectly normal slopes and profiles and waste cover on its sides. The two are at the same altitude and if one had good lighting (we did not) a interesting contrast could be shown in these two valleys in the same photograph. No other explanation can take care of this contrast.

On the south side of the trib. valley, just below the junction of the two contrasted valleys, is a deposit of very angular, wholly basaltic debris, heavily mantling the slope and making a definite convexity where it occurs. It is not talus nor local slope wash accumulating on its way down the hill. Tho no erratics were found and the structure is no longer exposed in the hiway gravel pit, the association of this gravel with the scabland is a clear genetic relationship Perhaps by itself, it would not be convincing. The eastern side of the coulee, however, has evidence of the same sort.

Back in a trib. valley is a large deposit of very angular, wholly basaltic gravel, cobbles and boulders, located at the sharp turn in the hiway by the well and camp place. Its summit is 345 fet above the coulee floor. Its bedding, poorly shown in a hiway cut, is foreset with dip diagonally out toward the coulee. There has been derangement of the trib's course in dissection of this fill and a small narrows has resulted. The deposit appears to have had fairly plane surface originally. There is no possibility of making this big debris accumulation a local affair. The failure to find erratics is puzzling but the marked scabland equally high on the west wall shows what has occurred.

Below this deposit is another, or perhaps a lower part of the higher one. It has been opened for hiway gravel.. It is well sorted but almost wholly angular, the degree of angularity very pronounced. Two foreign cobbles were found on the surface but none in the cut. Bedding shows rather poorly but in the back end of the cut is definitely foreset up the Coulee. Elsewhere, it is bedded parallel to the slope.

This deposit makes a convexity on the basalt slope, 100 feet from bottom to top. It lies on and adjacent to scabland knobs, here 30/ ft or so high. It is a bar, as surely as there are side-hill bars. Its summit is 240 feet above the coulee floor.

The great bar already known, on the west side of the coulee, traversed by a great loop of the hiway, measured 210 feet from bottom to summit. One erratic pebbles was found on it. Its valleyward face possesses great flutings which are nearly horizontal. They are not like terraces. The upstream terminus of the bar descends steeply toward the high rock cliff back of which the bar has been deposited. This looks like a constructional profile, as are the flutings and as is the very clearly marked lee slope back into the fosse.

Moses Colee here is 800 feet deep, if reckoned from the summit of the hiway grade out to the west. Most of this depth possesses steep but graded slopes with all the marks of normal valley slopes. Some structure may be involved but it does not show. The precipitous cliffs do not rise higher than the upper scabland along the west side. And the minor valleys which hang above the floor mouth at various altitudes between very slight notches below the cliff summits and deep cuts three fourths of the way down to the floor. How much of the original hang has been eliminated by subsequent downcutting isnt clear.

How harmonize the hanging valleys of Moses and Grand coulees with a hypothesis that calls for deepening by streams during interglacial time? Contrast with Snake River canyon which has no hanging valleys.

But whether the Moses Coulee cliffs here are the result of deepening or of widening the preglacial valley, it is clear that enormous erosion has occurred in the bottom of an older valley, this erosion producing a wide canyon with almost perpendicular walls. It is clear that as a closing phase of that erosion, or as a subsequent episode, great gravel deposits have been made on the walls and along the base of the walls of this youthful inner canyon. Perhaps two episodes of bar formation are involved, but each was tremendous and no long interval between is allowable, else the older higher bar gravel would have suffered more erosion than the lower younger bars. Both show but little, if any, effects of run-off.

Should one argue that interglacial stream erosion did the eroding of the inner canyon and that the gravel was in some way a product of glacial streams of no excessive volume, he must explain Douglas Coulee to the west where there is no scabland, no bar gravel, no inner canyon nothing but a normal valley that falls far short of entering the glacial stream canyon at grade. This is impossible to do and the conception of interglacial stream erosion producing the inner canyon of Moses Coulee fails completely to fit the field evidence.

Another crossing of Moses Coulee was made a few miles south of this, along the road from Farmer to Ephrata. Here the floor is 750 feet below the upland and 500 feet of this is preglacial., rather probably structural in part. Scabland extends 270 feet up from the floor. It marks a broad rock terrace on the west side here, presumably a structural terrace, the floor of the earliest valley here. The scabland is excellently developed, many striking buttes and knobs interspersed among irregular channels and rock basins. It is almost identical with that on the floor of Grand Coulee immediately west of Coulee City. No one would question that as glacial river bottom, because of the relation it has to Dry Falls. Here, however, it is 250 feet above the coulee floor and might cause hesitation in accepting as such. River cobbles and small bars, which are present, shd help to clear up the difficulty, tho some of the buttes are fully 50 feet high and completely isolated.

A great bar, probably at least 200 feet high, rests against the canyon's west wall north of the road. Other large bars, associated with a profusion of buttes and rock basins, lie up on this high rock terrace east of the coulee floor. Probably there is much more to the bar deposits here back into Sage Brush Flat than previously thought. If what is gravel-covered is bar material thruout, without rock knobs beneath, the figure of 80 feet probably should be raised to 100 feet thickness and the area covered should be quadrupled. In the absence of good sections and good evidence, however, this must remain inferential.

The width of the upper and wider part of Moses Coulee at this crossing is greater than any other place thruout the length of the coulee. It is definitely due to structure and the broad rock terrace on which scabland reaches its upper limit must not be considered as necessarily the preglacial valley floor. Lower terraces, eroded on various flows, may record the original preglacial floor, now greatly modified, but the there is no way of establishing this except by a careful study of trib. valleys.

The floor of Moses Coulee from Palisades down is a bar-marked floor, not a valley train floor. Even the gravel deposit on the north side at the uppermost orchards near Palisades, noted in 1922, is a bar. No volume of Wisconsin water, adequate for valley train making, came down Moses.

Columbia Valley, Wenatchee to Lake Chelan. August 2 1929

Except for two bar-mounded great terraces seen in 1928, nothing in the Columbia Valley along this stretch can be considered as having bar forms. The terrace remnants are not many and are all fairly definite terraces, without moundings or fosses.

But the situation is rather disconcerting, when one attempts to interpret these deposits as Wisconsin ~~or e~~ and earlier. There is a fairly continuous terrace or old valley floor, most of the way approximately 50 feet above the river. It is composed of rolled debris, prevailingly coarse, and would do well for Wisconsin valley train. But the mouth of Knapp Coulee, surely used by Wisconsin water out of Lake Chelan at the maximum of glaciation, has a sloping flat which is ~~far enough~~ above these terraces, above even the large 1000 footterrace on the east side of the river here. Its structure is not at all deltaic and indicates the presence of the main valley here either of ice, against which it might have been deposited, or of a complete fill up to this level. The Columbia now is below 700 here and the brink of the terrace in the mouth of Knapp is 1240, 540 feet higher. Can it be possible that more than 550 feet of material has been removed here since Wisconsin time?

Later-- It is possible, it is necessary! The Great Terrace, about five miles east of the lower end of Lake Chelan, is 1210 A.T. and there are remnants of other terraces 50 to 75 feet higher, not crossed by the hiway. South of the Columbia here, the slopes at this level and higher are strewn with great "haystack" boulders, left by the Okanogan lobe which also dammed Lake Chelan and forced Knapp Coulee to operate. The Wisconsin ice therefore is indicated and the Great Terrace, being lower than and behind the moraine, is later Wisconsin, as Pardee thot. Now, outwash gravel at 1210 on the Great Terrace, a little later than the maximum glaciation and the operation of Knapp Coulee, might well be a little lower than the Knapp Coulee terrace, 12 miles farther downstream but built at the maximum of the glaciation.

The return trip to Wenatchee showed clearly that there exists a perfectly adequate record of the largely eroded Wisconsin valley train all the way. A very large remnant, shown on the Chelan sheet at two levels, about 1000 and about 1100, lies on the east side of the Columbia opposite Knapp Coulee. Another remnant, seen in 1928 from the base only, lies just east of the edge of the Chelan sheet along the south side of the river. Its altitude is essentially the same as that of the Great Terrace. Below a point three miles north of Entiat, the Columbia Valley narrows to about one third of its width where Knapp Coulee enters and so continues almost to the junction of Wenatchee River, a distance of 15 miles. Due to this narrowness, most of the Wisconsin valley train has been swept away here. But from the west side of the valley, in the afternoon when the air is not smoky or hazy, two or three ~~two~~ remnants can be ~~seen~~ kept in view all the way. There is a clear descending gradient and there are only the faintest and most indefinite suggestions of higher terraces. Probably none of these are more than slope wash forms. Six miles below Orondo, on the west side of the Columbia, the hiway crosses a remnant which possesses two terrace tops 30 to 40 feet apart vertically, the higher one 744 ft A.T. Levelling from here across the river at other terrace remnants on the east side of the 1040 mid-valley butte shows them to be at the same level and a little higher. Two miles farther downstream, the terrace surface seen on the east side is lower and probably a product of dissection of the original fill. In the latitude of Valleyview School, the orchards grow up to the upper limit, or nearly so, of this same terrace (the Wisconsin valley train), here nearly 875 feet A.T. Here is a very extensive remnant, reaching along the river on to the Malaga sheet.

Thus in 35 miles, from the western end of the Great Terrace to Valley View School, the descent of the Wisconsin valley train is 335 feet, less than ten feet to the mile.

If, now, this interpretation of a Wisconsin valley train in Columbia Valley is correct, it will be verified by tracing it farther downstream into the region where the Spokane Flood waters poured into the Columbia and built their great bars. Many places must be examined, especially the region of Gable Mountain, to settle the question of the age of these great bars and channels. Another test will be a contrast in materials between the Wisconsin valley train, largely of non-basalt presumably, and Spokane gravels which should be dominantly of basalt.

No channelings, no bars, in any way comparable to the Gable Mtn. features, exist on the terraces here called Wisconsin. This should be a definite characteristic for identification and discrimination if in all cases there is also a vertical distribution of bar forms higher than plane terrace tops.

What might be taken for an exception to this statement of planeness of the Wisconsin valley train exists 8 miles of so east of Chelan along the highway. Here are marked depressions, 20 to 40 or 50 feet deep, in the terrace top. They are close to some large granite hills projecting out into, or isolated in, the gravel plain. In 1925 (?) they were taken for fosses. They are, however, ice block holes, incipient pitted plains.

The Okanogan moraine at Chelan overrode glacial lake silt and crumpled it in large irregular folds. The till, well exposed in a bluff of Chelan River below the new dam, is much thicker than down valley and the foldings suggest that the movement was upvalley. The marked moraine hills lie just to the southeast, farther down the valley. Furthermore, if this till were from the Lake Chelan glacier, there hardly would have been opportunity for a glacial lake to accumulate these silts in front of it, while if the Okanogan glacier was responsible, a lake in front of the advancing ice was unavoidable. Add to this, Runner's discovery of basalt debris in the till, possible only for the Okanogan lobe, and the case is complete.

Columbia Valley below Wenatchee August 3 1929

The supposed landslide topography on the south side of the valley east of the Wenatchee Heights remnant of the Entiat surface, is truly landslide. Climbed from Malaga to 2600 on Hardscrabble Hill. Everything above the terrace on which the Malaga school stands (760 A.T.) is landslide topography. A few granite boulders found on the lower slopes, up to at least 1300 ft A.T. These may be foreign or they may come from a concealed knob of granite beneath the basalt and the sedimentary formation which causes all the slipping. Nothing especially fresh in the slip forms shown.

The Malaga school terrace is composed of well-rolled cobbles and pebbles. Its structure is not exposed. Its surface is most curiously mounded into basins and hillocks that look very much like moraine topography. They surely are not slide topography. The features are not pronounced enough to show on the 25-foot contour interval map. They are apparently the same, however, as those on the terrace overlooking Rock Island Rapids, noted two or three years ago. And they are identifiable as far west as the terrace north of Mud Lake and some exist among the great slide blox of basalt south of the RR bridge. In a pit north of Mud Lake, the material is rudely sorted and stratified and almost all of well worn river cobbles and boulders. Basalt is present chiefly as boulders, tho not dominant among them. There is a clayey matrix but so little of it that the pebble and cobbles are all in contact. Not a fragment was found with

definite glacial markings on it. It seems impossible to call this a glacial till, yet it seems impossible to call the mound-and-basin topography anything else than moraine.

This same topography is very prominent south of the Rapids, extending over the area between the road and the river. Here its ~~loc~~ local relief is 30 feet and its total over the terrace ranges thru at least 100 feet. South of this morainic-like topography is another terrace, about 75 feet higher than the highest of the moraine-like surface, without a trace of such features on its gentle slope or on it flat top. Sections here show the same composition and structure as near Mud Lake. It is quite the most pebbly till I have ever seen, if it is till. In the sections overlooking the Rapids, this material is about 20 to 30 feet maximum thickness and rests on a light-colored silt whose thickness is not known but certainly 20 feet or so, perhaps 100 feet.

These curious moraine-like forms cover ~~the-te~~ most of the terrace south of the Rapids along the river for a mile and a half. They all occur in very good development on the east side of the river here, as far south as the 925-foot mid-valley flat-topt gravel hill near Columbia River Junction. Here thay have a perfect morainic surface, with short ridgings of variable shape and height and an abundance of kettles (undrained) among them. A local relief of 30 feet or more exists.

But the material of these hillocks, so far as shown on the surface is 99.99% basalt. Only six erratics were found by five of us in a 20 minute search. In contrast, the material of these mounds south of the Rapids, west of the river, has a fair amount of non-basalt and that near Mud Lake is largely non-basalt.

The altitude of the "morainic" terrace remnants ranges from 750 to 875, consistently becoming higher farther down stream. Consistently, also, any neighboring terraces, either higher or lower, do not possess these morainic features. A very curious and suggestive relationship seen at Malaga and at Mud Lake is the extension of the gravelly debris up on the slopes of the landslide topography which immediately overlooks them. These are steep slopes, too. It look like a smearing such as till might have; it doesnt look like river gravel habit.

The 925-foot terrace at the junction of Columbia and Moses Coulee is 99.99% basalt. Its western slope, like the western slope of the morainic terrace just to the north, is strewn with huge boulders of basalt, haystack rocks probably left by removal of finer debris but possibly being a separate boulder deposit on the riverward scarp of these terraces. It seems impossible that they are stream-carried. They are especially abundant approximately at the junction of Columbia River and Moses Coulee dreek.

The surface of the 925-foot terrace is almost perfectly plane. It is dust-covered to a depth of about three feet, below which there is well-rolled coarse gravel, cobbles and boulders on the edge toward the Columbia but only average gravel on the northern and eastern scarp. This great accumulation of basalt gravel continues to be a puzzle. And with the possibility, even the probability, that the irregular topography on the 850-875 foot terrace to the north is moraine, the problem isnt simplified.

One view is that the mounded terrace top is ground moraine, the ~~sc~~ scarp on the north of the 925-ft terrace is an ice-contact slope and the 925-ft terrace is the remnant of an extraordinarily high valley train which buries completely any terminal moraine. This view asks for a valley glacier from Wenatchee or Columbia valleys, reaching almost to the mouth of Moses Coulee. It requires that the ~~the~~ upper

part of the drift thus deposited be 99.99% basalt, tho it allows an abundance of non-basalt at Malaga and Mud Lake. It requires that the outwash be 99.99% basalt also. It is possible that as the ice tongue crossed into the valley with basalt cliffs, from Rock Island Rapids down, it encountered so much loose basalt gravel that this gave the surficial high percent. But to make the 925-ft terrace its outwash and to have in it no non-basalt (five fragments of non-basalt were found) seems impossible.

Another view admits the glacial origin of the mounded topography, but denies any genetic relation between moraine and the 925-terrace. That terrace is considered as a remnant of a great fill made out in Columbia River valley here by the scabland flood. This fill was 100 feet higher than the floor of the coulee just within the coulee walls, Bars there, along the sides, are nearly as high and the situation is conceived of as identical with that at Soap Lake in the mouth of Grand Coulee where this notable shallowing of the glacial stream is recorded in a nearly complete bar about 200 feet higher than the lake surface. After cessation of the glacial discharge, the Columbia crossed the bar in two places, the western channel later getting the upperhand and securing all the water. Thus the island-like position of the terrace and the steep scarp facing north and east. It is much more like a stream-cut scarp than like an ice-contact slope. The moraine is later and the ice stopped at the scarp base here.

Two accessory features of the Columbia Valley lend color to the second interpretation. One is the existence, on the west side of the river, just north of the mouth of Dry Gulch, of a terrace at 1000, a terrace whose surface definitely descends up the Columbia. If this should prove to be 99% basalt, its debris will be a Moses Coulee deposit, not a Columbia River deposit. Its slope then will be easily explicable as the descending grade of the big valley-mouth bar, of which the 925-terrace is the chief remnant. Also the bar in the mouth of Colocham, noted last year, will do as well as a remnant of this hypothetical coulee-mouth bar as it will fit the interpretation of last summer. Even better, for as a local unit bar, this deposit in Colocham has dips down the Columbia and there now appears to have been no spill down this part of the river

The other feature is shown in the cut east of Rock Island Rapids where the hiway climbs to the terrace with morainic topography. The cut shows much silt and fine sand and two members of fine gravel. The gravel is wholly basalt and wholly angular, blades and splinters being common forms. This composition is impossible for a fine gravel of Columbia River, for the river enters the basalt only a mile a nd a half upstream from this deposit. In contrast, the composition of the 1256 Liberty School bar-terrace is almost an arkose, there is so much granitic debris in it. The Liberty School deposit is normal, so far as composition goes, the hiway cut material is impossible material from upvalley. It must have come from the scablands and Moses Coulee is right at hand, only two miles farther down the Columbia. Furthermore, this black gravel is highly angular, with an abundance of chips, splinters and slivers and a few broken-rounds. It must be a product of the tremendous battering up Moses Coulee that is recorded also in the Three Devils cataract.

By this second view, which separates moraine and terrace as of different episodes, the ice tongue is subsequent to the Spokane Flood. Indeed, the morainic topography directly overlies the stratified fine gravel, sand and silt, this fine material thus representing the up-valley deposit out of Moses. This is only two miles up valley, a very short distance compared with the Snake Valley backwash. But, of course, a glacial Columbia was flowing at the time, even if no flood

came down it, and the glacial silt, finer than any loess apparently, and also colloidal, was from this source, settling in the pond made by the Moses Coulee bar. This idea of a Moses Coulee bar seems a feasible way to get ponding in the Columbia below the end of the ice which discharged the turbid water.

Yet there are features of the silt which may wreck this idea. It possesses what look like drying cracks along certain strata and there are paper-thin layers that seem impregnated with organic matter, also others that have dendritic markings that may be organic. These silts must be studied further.

Columbia Valley about Wenatchee August 4 1929

The case for morainic origin of the suspected topography noted yesterday is now fairly complete. Malaga gives the clue. The gravel extends up on the landslip topography to the south 125 feet higher than the Malaga school terrace. It is here simply a veneer or smear on the mixed basalt and shale of the slide. In one place, nearly half way between Mud Lake and Malaga, it is heaped up in a good lateral moraine ridge, the northern slope of which bears the glacial hummocky topography of the gravel and the southern slope below the ~~rid~~ ridge is simply the local slide material.

The composition of the ground moraine changes greatly with reference to some huge slide blocks of basalt near the GNRR bridge. The largest of these blocks stands 975 ft. A.T., 375 feet above the river at the north. West of these hills (upstream) the gravelly till is 35% basalt(north of Mud Lake) and 29% basalt (Malaga school). Immediately east, or downstream from the hills, the hummocks and hills are covered with large angular blocks of basalt and near the Valhalla school the debris in the hummocks is 86% basalt. This seems to explain the low percentage of non-basalt in the moraine east of the Columbia and north of the 925 bar-terrace.

The case for a Moses Coulee bar completely across the Columbia seems fairly well established by two more observations today. One is the character and composition of the Colocham Creek mouth bar. It is from 90% to 99% basalt, very angular, almost no rounded pebbles except non-basalt. Broken rounds are common, splinters, slivers and chips especially are common. This with the bedding which dipps back into the creek valley and the aberrant composition for any gravel down the Columbia shows that the bar idea is at least justifiable.

The other observation was made at the mouth of Dry Gulch, opposite Columbia River station. At 1020, a pit in the terrace here (noted yesterday) shows 90% to 99% basalt gravel, very poorly worn, with poorly shown foresets dipping westward out of the Columbia and toward the western valley wall. This fits in perfectly with the idea. Add to this that there is a higher terrace here, about 1200 ft. A.T., on the south side of the gulch mouth. It was not visited but at its altitude on the north side of the gulch, the material is distinctly arkosic, like the Liberty School bar-terrace, and therefore normal stream waste for the Columbia Valley here. If the 1020 gravel be called Columbia River debris, it must be similar to that higher. It is, however, almost all basalt, an abnormality that needs a special explanation.

If error has been made in interpreting this sag and swell gravel between Wenatchee and Rock Island Rapids as moraine, it can only be bar-~~covered~~-shaped river gravel and as such, it will be found farther down the Columbia. If morainic, it will have a definite down-valley limit. This limit appears to be approximately at Columbia River station and the 925-foot bar-terrace.

Whether the ice tongue came from the Columbia or Wenatchee valley isnt known. Traced upstream from Rock Island, the Wisconsin valley train rises relative to the moraine and probably buried whatever moraine there might have been farther upstream. Thus it is either still buried or has been destroyed in the erosion of those parts of the valley train which have gone.

Dry Gulch, south of Wenatchee, carries terrace remnants of arkosic gravel and sand at about 1200 ft. A.T. This material is largely unworn, tho some well rolled fragments are present. Basalt present but far from dominant. This is another remnant of the high-level arkose gravel and sand, older than any other deposits (thus far found) in Columbia Valley. (found this season(?))

Wenatchee River has a gravel-confined narrows just above the hiway bridge that is unusual. The gravel is obviously Wisconsin valley train and has foresets dipping up the Wenatchee. This gravel does no extend far up the valley, grading in a mile or two into sand and then into fine sand. No true glacial silt seen in the sections tho if the Wisconsin valley train of the Columbia blocked the Wenatchee there shd be a silt deposit upstream.

A feature of the lower slopes of the valley at Wenatchee and down valley as far as Mud Lake, below the level of the Wisconsin valley train, is the profusion of huge boulders of gneiss, some of them almost as large as a small shack. They cease abruptly down valley at a ridge composed of tjem, lying diagonally to the valley length, near the hiway near Mud Lake and lower than the moraine terace. They may record a tongue of ice down the Columbia but if so that tongue must have been pre-Wisconsin. It may antedate the morainic terrace also, the boulders being buried at the time the morinic terrace was formed and being left later by river erosion which removed the overvurden and left the larger boulders. They may, however, post-date the morainic terrace. They seem far too numerous and far too large for any river work. Their abrupt termination down-valley suggests ice deposition.

no trace of the morainic terrace seen up the Wenatchee as far as Cashmere.

The supposed bar in the mouth of the hanging valley just east of Rock Island Creek is not a bar. It has a terrace top, not a fosse back of it. Seen from well up on the slopes at the mouth of Dry Gulch. Its altitude is about 1300, or a little less, and it should belong to the Liberty School bar-terrace deposit. So difficult to reach it that the climb wont be attempted in the limited time at our disposal.

Wenatchee to Trinidad August 5 1929

Another puzzle solved this morning. The Liberty School bar-terrace is a compound form of moraine and outwash. This fact came to light from a traverse on foot from the east-west road across it south to the hiway, traversing sections 16 and 21. The surface along this traverse is diversified with hills and sags, some of them undrained depressions, amounting to 30 feet or more in local relief. One hill, on the east edge of the Wenatchee sheet (west edge of the Malaga?) along the road is 90 feet high on its west slope.

The topography looks as morainic as anything except linear ridges of drift. That it is not sand dune topography is obvious from the material; fine gravel mostly but containing many cobbles and even some boulders on the lower southern slope. It is true that clean well-sorted gravel isnt a likely composition for till but other features make the case clear. One thing is the fact that the southern slope carries several ridges parallel with the slope, as irregular in character as any typical moraine ridges and enclosing undrained linear sags

among them. The maximum relief of the most pronounced ridge and the associated sag on the uphill side of it (the north side) is 125 feet.

These morainic forms continue down the south slope of the deposit below the level of the lateral moraine southwest of Malaga. Gullies have modified the glacial topography somewhat but it is still very definite and clear. By tracing it down the irregular part of the southern slope and by finding it more gravelly, cobbly and bouldery at lower altitudes, its oneness with the morainic terrace at Malaga and the lateral moraine just to the south is clear. The Liberty School terrace, at least in its western morainic part, becomes a part of the record of this maximum glaciation of Columbia Valley.

The steep slope in the eastern end of the deposit has been produced by undercutting of the Columbia. This has destroyed the morainic topography that originally lay here and that carried the ice contact slope all the way from bottom to top.

Thus the back slope of the Liberty School bar-terrace becomes the outwash slope along the side of the ice tongue. Water from this apparently escaped eastward between ice and rock wall to the termination of the moraine near Columbia River station.

The Valley View bar must be similarly of this genesis tho it was not visited this season. Perhaps its morainic valleyward slope has ben completely destroyed. The great basalt boulder on its slope now can be explained as ice-carried. A puzzle still remaining is its composition. Why should moraine be so well sorted and so free from clay? Why should its higher lateral part be fine and its lower mid-valley portions be gravel?

The bar in the mouth of Rock Island Creek valley is almost wholly of very angular local basalt but contains pebbles, cobbles and boulders of non-basalt. It also contains finer interstitial material, chiefly granitic waste. It is here considered as a remnant of a lateral moraine of this maximum glaciation. Its summit is somewhat above 1100 feet A.T.

The silt and black sand in the highway cut east of Rock Island Rapids was re-examined. The supposed mud cracks are simply the product of dessication in the face of the cliff. Tho well marked for a few inches back in the silt, they become fewer and less definite until, three feet back, the same layers that carry them in the face are totally lacking in them. This is a pseudo-drying crack phenomenon that is worthy of note.

Pebbles of peaty material, very friable but with definite rolled shapes, found in one member of the black fine gravel. They appear to record an older swamp deposit, torn up by the scabland flood waters somewhere in Moses Coulee or nearer to the place of deposition. Much clay in some of the peat, some pebbles more clay than peat.

Sections in the east edge and south end of the 925 ft. bar-terrace examined along the Mansfield branch of the GNRR and the present big gully for flood water out of Moses Coulee. There is no varved clay and no sand or fine gravel in the sections. In one cut along the wash, fine sand or coarse loess overlies the gravel of the section but it is wind-blown, as amply attested by the numerous calcareous root casts in it at all levels. Elsewhere, all cuts and exposures show only basalt gravel, some of it fairly well worn tho not rounded and all of it poorly sorted and poorly stratified. The stratification in the RR cut thru the south end of the bar-terrace is foreset, tho not in the long deltaic style, and the foresets dip westward diagonally away from Moses Coulee and toward the west wall of Columbia River Valley. This location is two thirds of the way across to the west wall of the Columbia

and, more distantly, from the Liberty School outwash.

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The material in these cuts is so dirty and poorly washed that it might be considered a till. But the tilted position of many of the flat boulders indicates current in the same direction as do the foresets and one large boulder was seen with potholes and channelways drilled into and across it, still in place up in the deposit. It is therefore indubitably a river deposit.

The material in these cuts is almost 99% basalt. It therefore is not Columbia River gravel. But along the present dischargeway from Moses Coulee, there are numerous foreign cobbles and pebbles. These seem most probably to have come as outwash from the moraine at the north end of the 925 bar-terrace. Moses Coulee bars are notably lacking in foreign material. Another view would be that this erratic material is a contribution from the Wisconsin ice whose outwash was certainly very limited but certainly has plenty of foreign material in it.

The high terrace traversed by the hiway just on the south edge of the Malaga sheet (994 on map) seems to be a bar of the scabland Moses Coulee river. Its altitude is but little above the mid-valley remnant. Indeed, if one were to fill up the deep gully now discharging from Moses Coulee, there would remain a smooth flowing surface across from top of one bar and down its slope to the slope and top of the other This slope is comparable to the up-Columbia descent of the bar remnant north of Dry Gulch mouth. Both bar-terraces are composed almost wholly of basalt gravel.

These great masses of 99% basalt gravel in Columbia River Valley, their surface profiles flowing one into another, their lack of terrace relations and their foresets across the Columbia can not be explained as Columbia River gravel. There are no forms with which to correlate them, farther upstream, anyway. Here is an undeniable Moses Coulee deposit. It was made either by a Spokane Flood or by successive normal glacial discharges thru Moses Coulee. If the latter, its material would be mingled, during deposition, with Columbia River debris coming in simultaneously, it would have correlatives upstream in the Columbia, it would have terrace (rather than bar) profiles. it would not possess foresets dipping across the Columbia. It does not agree with any of these features. It is a splendid Spokane Flood deposit.

The contained boulders of this 925 ft bar-terrace are tremendously large for a stream to transport. They seem to have been the source for the "haystack" rocks that strew the bluff of the Columbia overlooking the RR tracks along the river. The till and moraine does not contains such fragments, even to the lee of the big slide-block hills by the RR bridge near Malaga. This means, then, that the occurrence of haystack boulders along the Columbia will be interpreted in the future as is has been in the past. They signify glaciation only up on the Okanogan Plateau. Elsewhere, they may be gravity-rolled blocks or stream-rolled.

The silt and fine sand of the hiway cut near Rock Island is not buried by moraine. The topographic expression of the stratified deposit is that of a terrace (with some dunes lying on it) lying against the moraine and 30 to 40 feet lower. The moraine topography comes down to the silt and sand deposit's terrace but does not continue across on to it. And it is not possible to trace the silt and sand in its Columbia River bluff any farther south than the terrace top extends. The bluff capped by moraine is heavily gravel-covered, a half of one percent being foreign, near the silt and sand terrace. The silt and sand may be back of this gravel, beneath the moraine, but this isnt demonstrable.

The silt and sand may well be interpreted as younger than moraine and as lying against a steeper slope of that moraine. The 925 ft bar-terrace is obviously either of the same age as the glaciation or is older. At any rate, this interpretation wont allow the silt and sand to be correlated with the 925ft bar-terrace. That interpretation seems possible only if the silt and sand goes under the moraine. This is the relation in the bluff directly south of the Rapids but it might be that the two silts are not of the same age or that the two moraines (on north and on south sides of the Columbia) are not.

The high bar north of Trinidad seems clearly to be shaped correctly for such a feature. It has a definite, tho shallow, fosse on the west. And its material consists of mingled basalt and granite, very fine gravel to sand. It may not be a Scablandbar. It may belong to an earlier series. The composition gives no clue. But it cannot be correlated with the Liberty School bar-terrace for that is related to the moraine and is therefore younger than scabland bars.

This assertion brings up an interesting question. Where is the outwash of the maximum glaciation, south of the moraine? It should be present in some of the terraces between the 925 ft bar-terrace and Trinidad. It should be lower than scabland bar gravel and higher than Wisconsin valley train terraces.

Is it possible to make the glaciation and the scabland contemporaneous? The abrupt termination of moraine against the 925 ft bar-terrace is very suggestive.

Vicinity of Trinidad August 6 I929

The Trinidad terrace, which continues back up the Willow Springs Draw, is a product of the Crater Cataract discharge. Its material is gravel with much coarse material in it. The gravel is all basalt. The terrace is sharply marked off from the much higher coarse sand and fine gravel deposits imkmediately north of Trinidad and thence westward for three miles. Its debris is altogether too coarse to have come past the lodging place of all this sand, unless it is an affair of a later episode and there are no correlative terraces at its level or to agree with any gradient it might have had. Indeed, there are no terraces at all up the Columbia for miles, tho great quantities of sand and gravel lie here, from II00 to I300 ft AT. down to river level.

The functioning of Crater cataract, therefore, did not occur when the great bars were built for they are as high as the highest scabland on the basalt bench between Trinidad and The Potholes, and as high as the head of Crater channel out of Quincy Basin. Yet both are the product of glacial waters of great volume. How to make thesequence has been for long a puzzle. Now a light has burst thru the darkness and all the new data of this summer are going to be fitted togehter without disharmonies, I believe. First, however, a bit of description.

The gravel along the north side of the east-west stretch of Columbia River between Cape Horn and Trinidad nowhere has terrace shapes though it ranges from river level (550) up to II00, two and a fourth miles straight west of Trinidad and south of the hiway. That it is now in original bar form, except for the perfedtly obvious gullying, is shown in the two big RR gravel pits along the GNRR. One pit is at the east end, just north of the lone ranch west of Trinidad, the other is a mile farther west at the south tip of the II00 foot isolated portion of the gravel fill.

In the western pit, the sections extend from 750, the RR level, up almost or quite to I000 A.T. Thruout, the material is poorly worn but fairly well sorted basalt gravel. Thruout, the bedding

dips down to the west, directly up the Columbia and exactly parallel to to the upstream slope of the bar itself. In several places, there are foresets in these dipping beds and the foresets dip east, against the dip of the gravel as a whole. If there is anything that can prove to a hard-boiled critic that these great mounds are bars, this should do it. The current which built the bar moved east, the material coming down from Moses Coulee. Yet the aggradation on the upstream face of the bar put 200 feet or more of gravel on it with dip conformable to the upstream bar face. Up this face, the current moved and locally was able to make foresets showing by their dip, their gradation of material and their decreasing amount of dip toward the lower ends of laminae that the debris added to this slope was moved here along and up a subfluvial slope. A river adequate to do this transporting, yet 500 feet deep, ~~was great enough~~ is thus recorded. Its central current was great enough, after bar accumulation had filled in the slacker places, to keep the channel from filling.

A cut along the hiway at the north end of this 1100 bar summit shows 100% basalt gravel, poorly worn, with foresets dipping west, not east. This must have occurred in an eddy, which the configuration of the valley favors.

The eastern gravel pit shows only coarse sand and fine gravel, very well stratified and sorted, with beds in the east end of the cut dipping exactly parallel with the slope toward the east, toward the face of Trinidad terrace. No current foresets in this; it is more like delta foresets. It is the lee face of the side-hill bar, structurally and texturally and topographically. (Intermediate sections, poor ones, show only horizontal or nearly horizontal bedding.) There is no interpretation, other than the one used here, which will account for these features and relations.

West Bar with its great ripple-mark-like hills may well be the bed of the gigantic torrent. It is 750 to 800 ft A.T., as high as the base of these sections west of Trinidad.

The structure of the Trinidad terrace does not indicate any delta here and sections go from top to bottom. It appears more like a deposit in a rising river, perhaps an aggrading river. It also has a suggestion of bar form, for its outer edge is 20 feet or so higher than the portion crossed by the hiway.

With apologies to those who do not believe in a Spokane Flood, I regret to announce that there probably were two of them. The first was the great flood which laid out the entire pattern of scabland channels and which did all the work in the Telford and Cheney tracts and down the Snake and back up the Snake and all the eastern tributary valleys. This flood deepened Grand Coulee sufficiently so more than any other spillway so that when, probably after an interglacial interval had passed and another glaciation advanced and started to retreat, Grand Coulee got all of it. "It" was the bursting of a glacial Lake Missoula, probably. Quincy Basin then may have had its greatest flood, or this second flood may have been less in volume than the first. It was this second flood which made the 3 western cataracts for no water was coming down Moses and no water was coming into the Columbia by way of the Snake and Esquatzel (No glacial water) There was then no ponding or overfilling except from the three cataracts and Lower Crab Creek. On second thot, this couldnt have been so big a burst or, no matter what by what routes, the Columbia would have been filled with the same enormous volume that is recorded in the bars, and therefore, even tho no bars were formed in the channels not in use, the Trinidad terrace and the three cataracts and Lower Crab Creek channel could not be formed.

Another difficulty with the new form of the hypothesis is to leave the moraine on Rathdrum Prairie uneroded by the second flood. It can be dodged in three ways. I- Ice still lingered in the Prairie valley and covered the moraine, the burst escaping over it.

2- the so-called Wisconsin channel is the route by which the second flood crossed the prairie.

3- The water did cross the prairie and its moraine, and the subdued character of the moraine is a consequence of that crossing.

It may be that the second burst, (for all these are postulated on the bursting of Lake Missoula,) occurred when the ice covered moraine in all cases. No, this wont work. Ice must be out of the Spokane Valley and the Columbia Valley as far west as the head of Grand Coulee. If it be kept that far back on the north edge of the plateau, it must be equally far back on Post Falls-Rathdrum Prairie moraine. Idea No One must be discarded at once.

Another idea that may be used to explain the cataract development after the bar-building and scabland ~~development~~ making in Columbia Valley west of the plateau is as follows. There was but one flood, one burst. This laid out the scabland pattern and all accessory features except the cataracts. It cut Grand Coulee deeper than any other channels. Then, with the waning of the ice sheet, the discharge from ordinary melting of the Cordilleran icesheet used the coulee, and if voluminous enough could develop the cataracts, the Trinidad terrace and the lower Crab Creek scabland. This hypothesis demands a very great volume, indeed, but it avoids tampering with Rathdrum Prairie for all the moraine on scabland and on bar deposits is younger and unassociated with any flood. How to avoid a flood during the later glaciation is a puzzle, however, for since this this is the most advanced moraine everywhere except on the plateau west of Grand Coulee, its ice most surely would make another Lake Missoula.

A test of the two-flood idea has been suggested in "Alternative Hypotheses for Channeled Scabland",--in the partial blocking by gravel deposits of the entrance of Crab Creek and Washtucna Coulee. The data at that time did not seem to indicate a sequence byt the vicinity of Adrian may show that the big bar nearly across Crab there is not Wisconsin in age, but second flood.

Vantage to Ellensburg Aug 6 1929

Both the Saddle Mts and Frenchman Hills anticlines rise to considerably greater elevations west of the Columbia. The hiway crosses from Vantage to Ellensburg along the structural sag between them. Both anticlines die out on the eastern margin of the Ellensburg structural valley. The northernmost range of the several crossed by the river (Yakima) between Ellensburg and Yakima is apparently the Priest Rapids Range.

Gravel terrace overlooking the Ellensburg flat from the east is composed of yellowish dirty-looking decayed material. Far older than any scabland gravel.

Ellensburg to Yakima Aug. 6 1929

The tortuous ~~course of the~~ canyon of the river should possess forms simulating scabland , if any normally eroded canyons should. Instead, itw walls are largely debris-covered and grassed and there are no suggestions of trenched spur buttes, side-hill gasshes, scabby cliffs or bar deposits. Also the gravel which lies in the canyon and which is cut here and there by the hiway grade is generally stained and weathered down almost to river level. Nothing much above the river looks as fresh as the scabland gravel.

Glacial Silts in Yakima Valley Aug. 7 1929

They are here! And they are exactly like the silts of Walla Walla and Snake Valleys. And they occur up to about the same upper limits. The hiway along the northern edge of the valley, paralleling the OWRR, has dozens of cuts between Union Gap and Zillah, in which these silts are exposed. Exposures ~~in Tennessee~~ range up to 35 feet in thickness, the substratum being well-worn, somewhat consolidated, unstained river gravel.

The material might be taken from the exposures east of the Columbia, they are so nearly the same in every respect. Even to the contained scratched, bruised and striated cobbles, the irregular pockets of tiny pebbles and coarse grains, the curvature of the bedding to conform to the cross-sectional profiles of the spurs, and the clastic dikes. There is good stratification, tho it is of the irregular type in Walla Walla valley and Snake River tributaries. Fine sand grades upward rather abruptly into a silt with indistinct lamination. The average thickess of these couples is about a foot. Nothing like the lamination of the varved silts in the hiway cut east of Rock Island Rapids. Some of the ouples are triples, with pebbly sand beneath the fine clean sand. These pebbly sand members are variable in thickness along any one layer, yet they are surprisingly persistent. Little of the irregular and separate pockets of such material was seen. No organic traces of any kind.

This undoubted glacial silt constitutes a definite terrace along the valley. Its surface is rolling and seems to constitute a drainage pattern dissected out of it subsequent to deposition.

The upper limits of this silt not yet clearly deciphered. A pebbly silt, poorly shown in a shallow section two miles west of Yakima at I200 A.T. may belong here but there was nothing else seen on the whole Yakima plain to be correlated with it. North of Zillah, the silt covers the dissected terrace up to about 950 A.T. It should extend considerably farther but there were no adequate sections to show.

Yakima Valley contains a lower terrace, shown as far up at least as Granger. This terrace is well seen as distinct from the present flood plain between Granger and Sunnyside, along the south side of Snipes Mtn. A pit at the brick plant in Granger, opened in the terrace, shows 45 feet of well stratified sand and silt, looking much like the glacial silt and sand, but lacking the irregularities of stratification, the evidences of settling and squeezing, the glaciated pebbles (even any isolated pebbles) and the ~~well~~ marked couples of sand beneath silt. On the other hand, it possesses certain features which are lacking in the glacial silt. It has a marked white layer, three inches in average thickness, I5 feet or so from the top, an excellent marker thruout the pit. It has a few calcified plant stems or roots well down in it, and it yielded the horns of a bison a few days ago and a scapula and antler a year or so ago. These fossils were found 40 to 45 feet below the level terrace top of the deposit.

Volc. ash

Tho there are a few layers which consist of a pebbly silt, there is no close similarity between these and the pebbly layers and pockets in the glacial silt. Moreover, this deposit is strictly limited vertically, not going above the top of the terrace while the glacial silt in characteristic phase lies much higher.

Vicinity of Sunnyside and Mabton Aug. 8 1929

The case for the glacial flood silt isnt as clear now as it seemed yesterday. There are two terraces above the floodplain level and the glacial silt, so-called, lies higher than both or is the higher and undulatory upper continuation of the higher terrace. The relations are best seen along the south side of Snipes Mountain, near the extreme western end of the irrigation ditch that leads westward past Baird from the vicinity of Sunnyside.

The vertical intervals separating river from lower terrace and separating the two terraces and the tops of the undulatory broad ridges of the glacial silt in all cases are about 30 feet. Sections in each are good. There is much that is similar in all. The characters seem in general to be those of floodplain deposits, with suggestions of local vigorous currents tho nothing more than seams or lenses or short thin strata of gravel occur. All three contain each a layer ~~of volcanic ash. The~~ of white, pulverulent, non-calcareous silt, probably either a diatomaceous earth or a layer of volcanic ash. The extent and persistence of each suggests ash. The layer in the lower member can be traced along the gully cut by the irrigation ditch spill way as far as the lower terrace extends back from the stream. Here it ends tho an excellent cut continues for a 1000 feet farther. In this cut, which is in the higher terrace, another layer of the white ash appears, 25 to 30 feet higher and not far from the same depth below the surface, 5 or 6 feet. The first layer is 6 inches to a foot thick, that in the higher terrace is ~~less than~~ 6 inches or less and is definitely and persistently double, a thin layer of clay or fine sand lying in the middle. This double layer, traced farther back from the river, continues parallel with the surface of the terrace to the end of the section. The section fails to intersect the rounded ridges of the glacial silt. In the road cuts thru this silt, a white layer, also double tho more irregular than that of the upper terrace, is present almost everywhere about 3 or 4 feet below the surface. Like all the irregular bedding of this higher deposit, the white layer conforms to the slopes of the rounded ridges.

This feature was a notable thing in the Pataha Creek sections seen last year (the rounded ridges with bedding conforming to their profile) It must mean something. It seems to record either deposition in mounds and ridges or a very uniform settling and slumping as valleys developed in the surface of an originally even surfaced fill. The latter view requires the sags to be stream valleys and their minor size means that they must be only wet weather drainways. That such should develop to the breadth and gentleness of slope these all possess seems very improbable here. There is no drainage today in them. It is not clear that they constitute a drainage pattern. If not, then the second hypothesis must be discarded.

If, then, these mounded forms and structures record uneven deposition, a cause for such must be found. It does not appear to be irregularity of the underlying surface for several cuts show the underlying Satsop-Hood River-Ellensburg gravel to have original surfaces beneath the silt quite at variance with the surface expression of the silt itself.

If the gap in tracing the double white silt layer from the upper terrace to the mounded glacial silt could be bridged, it could be known whether or not they are the same or are two different layers. That they are the same is possible, for the white layer of the mounded silt comes lower out toward the tips and lower ends of these rounded low hills and hillocks. Across the gap, it might actually dip down to re-appear in the silt in the upper terrace. Yet this idea finds difficulties for other features of the sections at the two levels differ

rather notably. The terrace sections show strata and lenses of stream gravel, the mound sections do not. The terrace sections do not show a coupled relationship of sand up into silt or clay, the mound sections do. The mound sections show much of the pebbly silt or sand with good and fairly uniform deistribution of the coarse grains while neither of the terraces show this development tho they do possess a pebbly silt or sand in some places. The mound sections have embedded pebbles, cobbles and even small boulders in the silt and the sand, obviously dropped from floating ice, the terrace sections do not show this. ~~-The-mound-sections-show-no-root-casts,-the-sections-in-both-terraces-possess-them.-~~ It is not difficult to find scratches and bruises on these pebbles and cobbles. Tho none found are really good cases of glacial planing and grooving, the marks can hardly be explained in any other way. The mound sections show no root casts, the sections in both terraces possess them.

There seem, then, to be three deposits of Pleistocene age in the YakimaValley ~~of-easte~~ south of Snipes Mtn. The oldest and upper most of them came from glacial water, the other two are of later and different origin, being essentially floodplain deposits. This interpretation requires either a considerable valleyward slope of the surface of the glacial silt, on the lower parts of which the upper terrace rests, or else a time of erosion of the glacial silt, to be followed later by aggradation. The two terraces seem clearly to require a period of erosion for their relations, tho no unconformity shows in the fairly good section.

Another section, forgotten when the above pages were written, was found about at the base of the mounded silt, at contact with the upper margin of the higher terrace. In it, the white layer of the mound silt ended on one side of the gully, the opposite side (a part of the upper terrace) not possessing it. This seems to show that there are two double layers, one in the mounded silt, one in the upper terrace.

A discovery of mammalian bones in the upper three feet of one section in the mounded silt is of significance. These bones are very fragile and not of any domestic animal. Not sure what they belong to. Scattered along about the same level. They seem to lie under a blanket of wind-deposited re-worked silt. Nothing like the characteristic features of the glacial silt was found at their level or above. But if they really belong to the so-called glacial silt, we must stop calling it glacial. How ice-marked stones dropped into silt ould harmonize with mammalian bones is difficult to see. It is much more likely that this herbivore (persumably) "wandered" thru the Yakima Valley when the terraces were being deposited. His remains, unlike the bison horn cores, were buried in wind-drift up on the slopes above the flood-plain level.

Anent the old Satsop problem, I am probably wrong. As Buwalda points out, there is re-arranged quartzite gravel in these terraces and in slope wash and this I took in some section to be the original bedding, unconformable on the tilted Ellensburg ashy shale. The section that convinces me that a gravelly member, highly quartzitic, lies in the Ellensburg is about three or four miles north of Zillah. Here the gravel is under at least 50 feet of Ellensburg ash and is tilted at the same angle.

Workmen report that the mastodon found at Granger about 1920 came from the bottom of the eastern upper pit which is entirely in the Ellensburg shale. What does Buwalda say about it?

Err.

South of Mabton along the hiway to Bickleton, various fresh glacial erratics were found up to 1040 and a few a little higher. Some of these are striated. Some look like the Belt argillites. At 940 a patch of about two dozen fragments of the granodiorite porphyry, associated with several other kinds of non-basalt, was found. Like the granodiorite in several other places in the record of the Spokane Flood, the patch seems to have come from the breaking up of one original boulder. It may represent the fracturing of two to several boulders, however. And the granodiorite was also found east of Sunnyside about 6 miles, on the road to Mountain View school. Here it occurs at the upper limit of all erratics, 1100 ft A.T., associated with several other kinds of rock.

Upper limit of erratics north of Prosser, on the road from one mile east of Lone Pine School, is 1130. Plenty of fresh boulders here of various rocks, some of them striated, some very much like the Belt argillites.

Upper limit of glacial silt not far east of Sunnyside Canal. Not very high above the ditch.

Yakima Valley Scabland August 9 1929

!?!

The final culminating piece of evidence by which the Spokane Flood hypothesis will stand thru all the storms of criticism lies in Yakima Valley between Benton City and Prosser. It is an assemblage of scabland rock knobs and buttes, rock basins, channels and bars that is utterly without explanation if the Spokane Flood hypothesis be rejected. There is absolutely no other way of accounting for the phenomena, absolutely none!

For 8 miles, the northern wall of the valley is strongly cliffed or scoured and the topographic map shows much ruged topography above these cliffs. This rugged topography is developed in a minor anticline running northwest from the Horse Heaven Hills near Erie across to flank the base of the long southern slope of the Rattlesnake Range. The ruggedness consists of rock basins nearly 100 feet deep, strikingly bold cliffs in the tilted flows, isolated buttes nearly 150 feet ~~abo~~ above adjacent basins, the whole in as intricate a maze as in any scabland on the plateau.

Bars here are splendid affairs, ranging from minor ones 20 to 40 feet high in the basins and in the lee of buttes to large deposits 170 feet thick and a mile long. There can be absolutely no doubt as to their character. Some of them are wholly down in rock basins and b beautifully shaped, some block preglacial valleys that crossed this tract from the north and some constitute the east wall of such valleys. Several large pits opened in different bars, in which the gravel is 99.99% basalt and quartzite (the quartzite from the Satsop-Hood River-Ellensburg gravel member), little worn to holly angular, some of it very bouldery (boulders of basalt) and all with foreset beds. In every case the foreset beds dip up the Yakima. The large boulders are mostly very sharp edged and clearly are freshly plucked. Many of them also have the staining on some faces that joint planes in the basalt possess, while other faces are fresh black basalt. There is almost no weathering of the deposit, tho a good deal of calcium carbonate coats the fragments. With the big boulders of basalt are granites, perfectly fresh, quite angular, up to two feet in diameter.

The foreset bedding is not strictly deltaic. It consists of a series of nearly horizontal groups or members, each foreset from top to bottom but separated by a thin layer of sand or fine gravel, or by a change in the amount of dip from underlying or overlying strata of

foresets. There are also changes in direction of dip tho all are westward.

The large boulders, indeed, all the angular basalt fragments, obviously came from the scabland exposed or under the gravel or under the broad silt-covered plain just to the east, north of Benton City. Excavation of these irregular channels and basins yielded a huge amt. of material and by far the most satisfactory explanation is that it lies in these bars.

The anticlinal character of the eroded tract is very well seen from the new highway grade on the south side of the river. Also the great disembowelling, like Gable Butte.

The easternmost of the bar deposits lies on the east wall of Corral Canyon, and extends from its entrance into Yakima Valley to the Sunnyside Canal, more than a mile. It is 100 feet thick. It may have largely filled the canyon originally but it did not cover the western wall which is all basalt and thin loess. Loess also covers the bar to a depth of two to four feet.

The westernmost bar seen lies similarly along the eastern side of Snipes Creek valley. It is half a mile long and 170 feet thick. The material in its southern part is largely basalt and very coarse and angular. In its northern part, it is finer in grade and has a large percentage of pebbles from the quartzitec gravel of the Ellensburg in it. Apparently, a local nearby source of this sedimentary is shown by this. It surely is all one deposit.

The evidence for a great current of glacial water up this portion of the Yakima is thus irrefutable. No one could see this place and deny it. But it is almost unbelievable, even when one sees it. The highest of this terribly scarred country is 950 ft A.T. and depressions among the rugged bare crags go down to 750 within less than a quarter of a mile from the highest point. Something like 200 feet of erosion in basalt occurred here and some of the basins, partly in rock, partly blocked by bars, are nearly 100 feet deep.

This scabland, developed on an anticlinal fold, can never be explained by Alden's alternative of collapsed lava caverns. The rest of the fold is all here, above 1000, with no sign of scabland or even of rock ledges of any sort.

If it is an unescapable conclusion that glacial water, flowing back up the Yakima, did this work in the constricted place in the valley here, one asks how many different episodes of this character were necessary. Only one is recorded, for the bar building is perfectly proportioned to the channels and buttes. One bar in one of the basins in 40 feet high and composed of boulders up to three feet in diameter. This doesnt record any later minor flooding. If but one eposide is involved, the volume of water passing over this scabland can readily be computed. The volume of Yakima Valley upstream from the scab and and below 1100 can be found from the topographic maps. This is all that can be allowed. It is even more than can be allowed for the last few tems of feet would have a greatly decreased current. The depth of current, real maximum current, over the scarred basalt summits, cannot exceed a hundred feet or so. And it all was essentially summit when the affair started. The time involved to fill the basin can be approximated in several figures, using different assumed velocities and dividing the cross sectional area here into total capacity of Yakima Valley below 1100 to the west. A correction must be made for the 100-foot figure for not all of the valley here had a floor as high as these scabland buttes. The preglacial canyons containing the big bars record a valley about as deep then as now. Whatever velocities be used, they should equal or exceed those in the Dalles today where the Columbia is not making scabland rapidly enough to be mappable.

Whatever figures may be arrived at, it is perfectly obvious that the Spokane Flood hypothesis will demand a very, very short time; a few days or a few weeks at the most.

What a discovery this is! How faint my faith, that I never dreamed of finding real scabland of the plateau type in the Yakima constriction.

Sillusi Butte August 9 I929

No definite scabland or bar forms here, and, without other forms across the river, the flood hypothesis would never be applied to the butte. Yet there are scabby ledges and crags where normal erosion profiles and surfaces would not have them. And a notch between the high crag at the south end and the next one to the north has a spatulate shaped deposit spread out to the west of it and lower down. This may be a gravel bar. It is not a dune sand deposit, in terms of dune growth today, tho its location makes it look as tho wind blowing westward thru the notch had made it.

The supposed long bar trending west from the Plymouth-Kennewick road in the lee of Sillusi Butte has ledges of basalt along its southern crest. It isnt all bar, at any rate. Very difficult to do anything with the question of bars in this region, for there are no sections and wind driven sand mantles everything except the basalt cliffs.

The map shows three or four depressions at the west base of Sillusi Butte but these may have been caused by wind-driven sand.

Kennewick August I0 I929

The road to Plymouth crosses a broad gravel ridge about 700 ftAT. five miles out of town and between the two elevations I025 on the west and II93 on the east. No structure in the ridge but a short distance to the south, back of it, is a pit examined in I927 with good foresets dipping northward and with foreign material in the chiefly basalt gravel. This was then thot to be a slope wash deposit from the hill to the south, tho that wasnt a satisfactory explanation even then.

Now it appears that this gravel is a bar accumulation, It largely blocks the drainage and it lies properly for a flood bar. Its composition is OK for a bar, especially in the presence of large angular basaltic cobbles.

Probably the structural flat crossed by the hiway between Richland and Kiona, summit of the road climb, is covered with bar gravel. It is fluted correctly for currents across from the east and its composition, mostly Ellensburg gravel, nevertheless contains large boulders of basalt and some of fresh granite.

Highest erratic nest on the road toward Plymouth out of Kennewick is 990 ft A.T.

Er.

Iowa Flat and Cold Creek Valley Aug. II I929

The flat carrying the irrigated tracts north of Benton City is not a silt flat. It bears silt or loess superficially only. In many places, boulders of basalt have come to light in road grading, ditch digging, etc. and in the northeast part, close to the slope down to Yakima River and on that slope, the boulders and cobbles constitute the surface itself. This flattish tract is not plane, either. Its broad gentle swells are bar forms, leading southwestward and westward to the big bar front on the east wall of lower Corral Canyon.

Er.

Erratics are fairly common along the road up from the Yakima half a mile from the west edge of the Pasco map.. Highest at II05 and II09

Since the Mission moraine is strewn with Deltian boulders + Polson moraine has very few there on it, one might argue that the Big Burst of glacial Lake Missoula was of Mission age, rather than Polson (Wisconsin).

A road from the gas wells east across Cold Creek Valley to the Kennewick-Hanford road. From 825 down to 625 is a most startling development of huge piles of iceberg nests. More than a dozen can be seen from any point on the road. Some of them are 15 to 20 feet high above the highest ground around them. and 100 feet across. The slope actually looks morainic, except that there are no enclosed basins, no ridging of drift and only a thin scattering if any erratic material between the mounds.

The mounds can hardly fail to be as thick as they are high for th they are distinct pimples on the sloping structural plain that bears only minor gullying elsewhere as a modification. Basalt not seen outcropping, the plain evidently carrying a thick deposit of some kind of silt, or , rather plausibly, being a bench of Ringold at the foot ~~o~~ of the Rattlesnake Range.

The debris in these piles is highly varied in kind of rock represented. Of the 6 examined, four had no Columbia River basalt while in one, the Columbia River basalt is very common, all of it in weather-fractured fragments. The mountain three miles away and nearly 3000 feet above could easily be the source of much basalt waste to come down onto this plain and to be carried across it. But such debris could hardly be in the mounds which are clearly constructional ~~forms~~ piles above the slopes on which locally contributed basalt would travel. Some of this berg ice must have carried much basalt, tho most of it was basalt-free. The icesheet from which these bergs came impinged somewhere on the northern edge of the basalt plateau.

The most common constituent of the berg debris probably is granite. Slate, argillite and finegrained quartzite ranks high, the various textures and especially the colors and the mudcracks, ripple marks, thinness of stratification and fineness of grain demand that these bergs be traced back to mountain ranges composed of the Belt series. Granodiorite porphyry, identical in every way except in abundance of basid segregations or inclusions, is fairly common. One place has at least 30 pieces of this rock scattered over a radius of 25 feet. At least 30 different localities , from 100 feet to half a mile apart, in which it was found. This is another evidence of the derivation of these bergs from Idaho, Montana or adjacent British Columbia.

Very little gneiss was found. If the ice had come down the Okanogan from that part of British Columbia, the Shuswap gneiss would have been a prominent constituent.

The size and abundance of bergs stranded here is amazing. It seems a wonder that, if they came down the scabland channels, there are not plenty of such features thruout the scabland pattern. Perhaps lodging and melting in one place was impossible, perhaps the debris once deposited was re-distributed. But there are plenty of slack-water places where these mounds shoudl occur.

Another puzzle is the 200-foot vertical range. The lower mounds can hardly record berg-standing simultaneous with that which made the upper mounds. Apparently a rapidly subsiding water body is recorded.

Ice markings, i.e. striae and smoothed surfaces, are common on the fine-grained rock fragments. One can see them from almost any point where he may choose to stand. They are commonly ~~of the~~ short and not rarely slightly curved or with angles in their courses. In this respect they are like the scratches on the pebbles in the Yakima Valley silt near Snipes Mtn., whose departure from conventianal parallel striae along the full length of the cobble raised question as to their truly glacial genesis.

Cold Creek Valley here is without possible question a constructional valley, resulting from the growth of bars over from the Spokane Columbia. It is too wide for a fosse, apparently. The bar gravel

is splendidly shown in the clean washed slopes east of the road crossing.

Koontz Coulee Aug. II I929

That this large trench is no true valley, but is a channel, is evident from the large bars which flute its floor. There is no flat floor in any cross section of it. Every ranch well has a pile of large cobbles and even boulders two and a half feet in diameter alongside. This is true even in the broadest, least accentuated portion where the road leads directly east to Mesa. Nothing but a huge stream stream across this whole flat could have transported them here, out in the Ringold silt plain.

A beautiful side-hill bar lies up against the scabland walls east of Mesa. Best seen from top of west wall or the hiway from Ringold.

Bar gravel filling and blocking the old Palouse at Connell is well ~~shown~~ seen from the road west out of Connell. Frontal depositional slopes face south. A large pit in the west part of Connell in it.

New cuts along the Milwaukee between Othello and Warden, vicinity of Novara, show a fairly uniform deposit of basalt gravel on what is probably Ringold, a thinly bedded, horizontal yellow silt. Gravel 6 to I0 feet thick, with foresets dipping south. Highly calcareous in upper part, almost the upper half looks white. Seen only from the road.

Thick Ringold or possibly Ellensburg is exposed in the lower part of Lind Coulee, north of the soda lake of Drumheller Channels. It is thicker than that exposed along the road from Warden to Neppel, tho no more than a mile or two from it. Here should be a good opportunity to prove, if necessary, that scabland does not underlie the cover of sedimentary rock and also to learn if the sedimentary is tilted. Its presence here indicates the descent of the basalt surface north of the anticline below the Quincy basin.

Ephrata and Soap Lake August I2 I929

Large numbers of large rolled boulders lie along the hiway from Ephrata toward Soap Lake. Many are four feet maximum, some are 5, a few are 6 ft. maximum diameter. They seem to have a lower limit below which they do not go. This is not far from the altitude of the Ephrata "channel" floor, the boulders lying on what corresponds with t the south wall of this channel. Is there any possibility that they are morainic, instead of fluvial?

Soap Lake I90 feet by aneroid below Ephrata, ~ 1087 G.T.

Good exposures of abraded surfaces of the basalt on the isolated ledge that makes a separate cliff at the southwest corner of the lake, north of the northernmost hotel. Clearly not glacial A good well polished surface uncovered and not a trace of striae or scratches. Imperfect groovings and incipient potholings also indicate the stream origin of these markings. Columns here are very large and perhaps didnt pluck very well.

Highest erratics along the north-south road, north fron the hiway N-S limb just east of Ephrata, are I437 ft. A.T. At about I400 is coarse, subangular basaltic stream gravel with erratics. Above this is simply the slope waste and loess and sand of the basalt hillside. A hill stands out toward Soap Lake, lying between this road and the lake, easily seen as one approaches Soap Lake for the first two miles out of Ephrata. It is a part of the Soap Lake anticline, its summit not much above 2000 A.T. Between it and the main monocline is a broad sag I750± ft. A.T. It is quite unscarred by glacial water and free

(The Soap Lake anticline can be traced as a topographic feature as far as Ephrata, lying in front of the major folds)

from erratics. Whatever made these enormous scabland features of this region did not reach this high, tho it came within 180 feet of reaching it.

The lower end of the abandoned eastern lower coulee again examined. It is possible to drive from Ephrata and Soap Lake, along the west side of the lake, all the way to this lower end. Here in the floor of the main coulee is a bar 70 feet above Alkali (Lenore) Lake. It may well be Wisconsin in age. Also a nearly plane surface underlain by gravel and 50 feet or so above Alkali Lake, extends for more than a mile along the east side of the main coulee between the two lakes.

A steep climb is necessary to get up into the lower end of the abandoned higher eastern coulee channel The main floor up here is 420 feet above tha lake (Alkali). This is approximately the altitude of the base of the great bladed salient at the south end of the rugged divide separating the eastern and western channels. The eastern channel floor has been trenched a hundred feet deep along its lower mile, this trenching necessitated apparently by the descending surface, northward, of the resistant flow which constitutes the floor of the east channel. The end of this inner channel is a cataract cliff, also about 100 feet high. But the existence of a fine bar here, lying along the east side of the alcove formed by the retreat of this cataract, the top of which is almost as high as the lip of the fall, proves that the current which made the fall, made the bar and therefore that the cataract was subfluvial. There could have been no descent of the surface of the great glacial river over this fall.

The bar is 250 feet high on its lower end, descending to the level of of the 70-foot bar along Alkali Lake. Therefore, the western or main channel was within 70 feet of its present depth before the higher eastern channel was abandoned.

Less than a thousand feet upstream from the lip of this subfluvial cascade is a rock basin in the middle of the inner channel, 100 feet deep. Its upstream lip is somewhat notched and its western wall is fairly gentle and mantled with debris. But its east and south wall are essentially vertical. Is this a plunge pool? Can plunge pools and subfluvial cataracts be harmonized? Yes, if the vanished cataract, to which the plunge would be ascribed, was high enough above the surface of the great river in the main channel.

Good remnants of the worn, abraded, even polished floor of the ~~in~~ inner channel to be found between the plunge pool and the subfluvial cataract. Here again is evidence that locally at least the basalt was really smoothed and abraded fast enough so that plucking did not destroy all records of it.

Soap Lake and Moses Lake August 12 1929

The great back slope of the gravel fill south of Soap Lake is an impressive feature whose meaning cannt be escaped. With the north end of Soap Lake as a center, an arc with 6 mile radius struck from Ephrata to Adrian will approximately fit the high rim of the funnel-shaped slope. From Ephrata to the south end of Soap Lake, the maximum descent is 250 feet from rim to funnel mouth. The slopes are all very well seen from the top of the hill out of Soap Lake town. Here also is apparent a high bar, approximately as high as the rim, lying along the west side of the funnel against the higher basalt hills. This bar has blocked runoff from these slopes into Soap Lake basin and has been trenched by a narrow gully in one place. An aggraded flat back of it, not seen from this viewpoint, adds to the argument for bar origin. Structure of the bar not shown in the gulch but the ridge form is apparent even from the back or west side.

The rim is not everywhere of the same altitude. It is perceptibly lower in its central portion, a little east of south of Soap Lake. Yet there is no definite notching of this rim except for the very insignificant valley less than a mile west of Soap Lake station (Grant Orchards PO). This feature at the rim is not 50 feet deep and not 1000 feet wide tho it widens out and deepens consistently southward toward the head of Moses Lake. No notch leading toward the Adrian Sink and the head of Willow Creek channel was seen.

Altitude of the floor in the notch west of Soap Lake station is II27 A.T., 75 feet lower than the station and I50 feet lower than Ephrata. Its walls, if 50 feet high, make the rim altitude not lower than II75. The rim at Ephrata is 60 feet above the town or I337 A.T. The range in altitude of the rim therefore is about I60 feet.

Perhaps this was not all in the original profile. The capacity of the notch here is far too slight to care for the water which eroded the channel now occupied by Moses Lake. There must have been a wide overflow sheet at the inception of the Wisconsin discharge, anyway, and it appears that only a small part of this spill become concentrated into the channel. The channel widens at the Hatchery and still more at the hiway crossing and, seen from the top of the hiway grade on the east, there are broad imperfect terraces descending southward into the channel from the rim.

If this be correct, Wisconsin water flowed over surfaces I200 AT here to escape from the Soap Lake basin. Indeed, this is a necessary conclusion if the Willow Creek spillway south out of Adrian is to be considered Wisconsin. The floor here is approximately the altitude of the station, I234 A.T.

A traverse south to Neppel and north to Gloyd and Stratford does not help much in resolving the riddle of the topography of this great mass of gravel in Quincy Basin. The highest portions, above I200 for an approximation, are to be correlated with the equally high gravel about Gloyd and must be of the same age as the high scabland in the angle between Crab Creek and Willow Creek. The lowest surfaces, occupied by Moses Lake, Rocky Ford Creek, Willow Creek and perhaps Ephrata channel are to be correlated with the Wisconsin discharge. They are erosional surfaces, except for local well-developed bars.

There seems, however, to be an intermediate terrace-like surface, abutting against the base of a steep scarp in the highest gravel but in other places appearing to develop simply from the high gravel surface by descending at a slightly steeper gradient until it lies alongside as a lower terrace. This feature is found along Willow Creek and along Moses Lake. It has scarps descending to the Wisconsin channels. In one place, a strand of it appears to cross from Willow Creek to Moses Lake. It may be tentatively considered as a record of an earlier division of the great fill, the idea being fathered by belief that a record of a second flood should be found. But unless good substantial evidence for this second flood is found elsewhere, this conclusion will be of little worth.

In both the intermediate terrace and the highest gravel, foreset dip southward in the hiway cuts along the east side of the lake.

A small tributary entering Crab Creek from the south, half a mile west of Stratfod station, has a fine bar blocking its mouth, now trenched. It is more than 50 feet high and its structure shows foresets dipping down Crab Creek on its face, and badk up into the tributary in its back slope. Scabland covers the spur in the upstream angle between this tributary and the main valley, and large boulders have been rolled off the spur and back into the tributary.

The scabland in Willow Creek channel floor ~~forr~~ south of Gloyd is simply an extension of that east of Gloyd and unburied by gravel. It is illogical to consider it a product of the channel drainage. The same conclusion applies to the scabland in the floor of Rocky Ford Cr. channel just above the fish hatchery.

Adrian and Stratford Vicinity Aug I3 I929

I can find no evidence here of a spill thru Grand Coulee of Grand and Dry coulees after Crab Creek river ceased to flow. There are two places where a suggestion of such a sequence may be seen but neither are as well explained by this hypothesis as by that of one ~~flo~~ flood.

The Adrian terrace of previous notes certainly has a sloping top, the gentle descent being to the west and to the north. The manner in which it slopes back toward the scabland channel of Dry Coulee suggests strongly the back slope of the gravel deposit south of Soap Lake.

East of this terrace is a channel about 60 feet deep, its floor terminating in a lower terrace up onto which the hiway climbs just ~~no~~ north of Adrian. It is the lowest part of Dry Coulee. East of ~~it~~ is a broad rolling gravel flat nearly as high as the Adrian terrace in its highest part. This terrace or rolling gravel flat descends gently northward toward the north wall of Crab Creek Valley and even more gently eastward up Crab Creek. It looks very much as tho this also were a subfluvial gravel slope, adjusted to the great current westward down Crab Creek Valley. This eastern slope extends east beyond the big orchards here, within a mile of Stratford.

The channel, 50 to 60 feet deep, which separates these two prominent gravel fills may be considered as simply the deeper portion of the glacial stream out of Dry Coulee or it may be a later affair. For a long time, I thot of it as a Wisconsin channel. Its altitude at the end of the channel, just north of Adrian, is I284, 50 feet higher than Adrian which is essentially on the floor of the Willow Creek channel. If the Wisconsin discharge out of Soap Lake basin thru Adrian Sink into Willow Creek channel were 50 feet deeper than the discharge thru Dry Coulee, this difference in altitude would ~~be~~ offer no difficulty in the use of this interpretation. That it probably was that deep seems indicated by the fact that the very head of this Adrian Sink-Willow Creek channel, on the east brim of the Soap Lake depression, is I200 ft. A.T. The upgrade of 34 feet to Adrian is a channel feature for a large river, not for a shallow stream.

Yet this Dry Coulee inner channel in gravel is not a good clean-cut channel feature and it may yet be that no Wisconsin water ever came thru it. In such case, there is no need to concern oneself about the 50-foot difference between the two channel floors.

Another feature that must be considered is the structure of these gravel deposits. Exposures are limited. The Adrian "terrace" shows west-dipping foresets in the scarp-like southern front along the north side of Adrian Sink and the head of Willow Creek channel. So does the gravel in the lip of the Dry Coulee inner channel. In the southern slope of the orchard gravel "terrace", east of the inner channel of Dry Coulee, the GNRR has a large pit in which the gravel is almost all foreset and in which the foresets dip prevailingly south, tho some dip southeast and some southwest. Some of the southeast dips are along the hiway grade up the east wall of the inner channel. This looked at first like the record of a big stream down Dry Coulee after Crab Creek River had ceased to flow. But most of the gravel here was deposited under the influence of both great glacial streams meet-

ing essentially at this place.

The notable constriction of Crab Creek valley bottom just east of Adrian, comes at the location of this GNRR gravel pit. From the hiway, the stream bed or the GNRR , itlooks rather significant of a preponderant discharge from Dry Coulee, or a later discharge after Crab Creek river had ceased to flow. But its scarp is not more than a hundred feet high and the marked scabland knobs on the south side here are not 30 feet higher. Seen from the top of the gravel deposit and a thousand feet or so back of the brink, these scabland knobs seem buried almost flush in a gravel plain. Seen from the higher scabland buttes a mile to the east, with the vertical element notably reduced tho the full height of these buttes in view, they become only channel floor buttes, mid-channel buttes in position, for the preglacial river floor (gravel flat and butte tops) extends well south of these buttes. It is from this viewpoint that the channel relations are best seen and understood.

There is another place where relations suggest a sequence in operation of Dry Coulee and Crab Creek rivers. It is the highest marked scabland in the interstream angle between Dry Coulee and Crab Creek valleys. The scabland here is developed on the east side of the spur in a way that indicates the work of Crab Creek river. But the gravel deposit here (I400 ft A.T.) overlaps apparently from the west, as tho thrown eastward out of Dry Coulee after the scabland had been eroded.

This may not record any sequence. Even if it does, that sequence may be simply a change in capacity or in depth at the head of Grand Coulee during the episode, allowing more water down Grand (and therefore Dry) relative to Crab; perhaps even a decrease in Crab for that same reason.

Several splendid bars lie in Crab Creek near Stratford. At least three big ones ~~that~~ along the northern wall that I havent noted before. They are really continuous past minor headlands. One climbed north of Stratford by party last year when waiting for the Princeton special is 200 feet above Stratford and is really compound, a lower one lying on the valleyward ~~side~~ face of the large one. Excellent fosse development back of all. Another large one along the road to Coulee from the big orchard tract west of Stratford. It also has a fine broad fosse, the blocked mouth of a preglacial tributary valley here.

Two miles or two and a half miles east of Stratford on the south side of the valley is another fine bar, I40 feet higher than the RR grade. A very good fosse back of it. A pit in it shows foresets of fine basalt gravel dipping back toward the valley slope. This bar nicely fills and smooths out a large southward bend in the preglacial Crab Creek valley. Just north of it, on the opposite side of the valley, is a fine scalped ~~spur-of-se~~ and truncated spur of scabland. The ensemble can be explained only by the flood hypothesis.

Another large compound bar lies as the south side of the valley two or three miles west of Wilson Creek A road climbs southward over it. Not travelled.

The bar group just west of Wilson Creek re-examined. I will ~~st~~ stick to every statement made in print concerning it. This is a wonderful place for critics to visit.

Grand Coulee

Hartline Basin is an integral part of Grand Coulee. Its gravel deposit is simply a huge congeries of very broad, flat bars, tailing out into the Deadman's Draw scabland and terminating on the east for most of that margin as a very definite scarp or bar front, 30 to 60 ft high, overlooking lower country that is mostly Palouse loess.

Every gravel exposure shows structure that agrees with this interpretation. Foresets are present in every cut and in many, the structure is essentially all foreset. In the eastern part of the fill foresets dip east, in the northwestern part (top of hiway climb out of Grand Coulee) they dip northeast and east, and in the southeastern marginal part, they dip southeast. The northeast dip is clearly the product of an eddy in the lee of the scabland salient between upper Grand Coulee and Hartline Basin. Only a broad sheet of vigorously flowing water out of Grand Coulee could put this gravel over this broad area and could give it the structures it possesses.

This gravel terminates on the south, against the scabland, in two different ways. For a few miles east of the Grand Coulee complex of canyons south of Coulee City, the gravel slopes up toward the south and has scabland, with patches of gravel, south of it and higher than it is. East from the old Arbuckle place, strongly expressed, deeply trenched scabland, in buttes and channels, lies south of the gravel and lower than it is. Here the gravel terminates in bar forms, the largest bar having a southern and southeastern facing scarp 30 feet or so high.

The scabland mapped as isolated in the southern part of Hartline Basin really is continuous up into the basin from the district south of the gravel. It is less in extent than formerly described, probably not exceeding two square miles in area.

The pre-scabland Palouse loess of Hartline basin still underlies the flood gravel in at least one place. At the east corner of sections 25 and 36, T25N, R28E, the debris from a dug well still lies heaped up about it. Gravel lies on the west side and Palouse loess around the other sides. From relative proportions, for it was not mixed, about a fourth or a fifth of it is gravel. From timing cobbles dropped into it, the well is about 100 feet deep, and thus about 20 to 25 feet of gravel overlies a buried loess here. This indidcates that the gravel fill is certainly not everywhere as deep as the scarp facing Coulee City is high. Since the location is only about a mile east of the scarp, this seems to show that a preglacial loess-covered surface probably extended westward across the structural basin which constitutes the coulee here at an altitude somewhat above the present eroded floor.

This is about 1¼ mi. from Ephrata's Ranch where Bryan found stamped gravel in a well. Gravel shld be pre-loess

Another and more striking case of scabland gravel above Palouse loess is in a very high and massive bar a mile or a mile and a half north of Bacon, and just west of the Soap Lake-Coulee City hiway. Both sides of this bar, the east and the west, show outcrops of the loess up for 30 to 50 feet above the base. Above this is at least 150 feet of gravel in a splendid bar form, projecting southeastward from a high scabland tract to the northwest. Clearly the flood here did no erosive work. A structural slope descending southeastward carries the basalt down about 300 feet in about 3 miles. The structural basin to the southeast, confined on the south by Pinto Ridge, must have carried as thick a loess cover as anywhere in the region. This 30 to 50 feet beneath the bar is all that is left of it. Both east and west of the location of the bar, it was swept off and the basalt was eroded into scabland forms. Here there was little or no erosion. The lack of erosion may have been due I- to the presence of a high knob originally in the upstream direction, northward, or

2- to deposition of a complete mantle of gravel all along this structural slope in the initial stages of the flood, and the erosion of most of it in later stages when the splendid canyons to the right and the left were developed.

It is certain that the bar is a shape left by great currents on either side. The exposures of loess on both sides are certainly erosional and this argues that the remainder of the slopes, in gravel above the loess, are also erosional. The second explanation thus seems to be favored.

Later-- Seeing this great bar (I560 base on south side, I820 summit) from the Pinto Ridge view point south of Bacon adds an item to this interpretation. The erosional slopes are only the lower 75 to I00 feet, all the rest is in gentler, smoothly flowing true bar profiles. The original deposit therefore was a bar I60 to I90 feet high above adjacent depositional surfaces, also bars in genesis. The cutting of the canyons on either side made possible the removal of such flanking lower gravel deposits and left the erosional scarp bordering the lower slopes and exposing the loess. Thus an initial higher tract northwest of the bar (upstream) is required. The two coulee canyons therefore must be considered as preglacial drainage furrows similar to those now on the slopes of Pinto Ridge and High Hill above the level of the flood.

The ~~only~~ way these great bars of the structural depression north and east of Bacon point toward Spring Coulee is very interesting. Not one bar, except in or very close to Dry Coulee or Lenore Canyon, ~~are~~ is oriented for flow out thru Dry Coulee. Spring Coulee thus appears to have been the preglacial outlet of the depression. That it carried an enormous volume is more obvious now than ever before. Seen from above, scabland lies back of its cliffs in strong development. A pronounced subsidiary canyon, never seen before, parallels Spring Coulee along the south side close to the head of Long Lake. It is ~~no~~ more than a mile long and has a good cataract cliff in it, and numerous buttes. Between it and the main Spring Coulee is a splendid elongated mid-channel butte, the north face of which makes the prominent crags here along the south side of Spring Coulee.

Highest erratics on the north slope of High Hill are I850 A.T. This is higher than any other upper limit in this latitude in the Grand Coulee region.

Lenore and Dry seem to have had their greatest erosion after the great bars of the Bacon depression had been formed. Likewise, the flood over the south edge of the Hartline basin seems to have been ~~dry~~ drained off by this time, else the bar forms would have been modified to show spill thru Dry Coulee. (I wonder if this is right. Better think it over after the map is completed)