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THE GLACIAL LAKE MISSOULA[1]

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The object of this paper is to show that in comparatively recent time an ice-dammed lake filled a large part of the drainage basin of the Clark Fork in northwestern Montana.

To prove the existence of the lake is set forth what evidence has been found in the literature of this region together with a contribution by the writer, whose observations, made at odd times during the past decade, were confined mainly to the Missoula and Bitter Root valleys.

Belief that the lake was ice-dammed was sugggested by certain of the phenomena of this area, but is based mainly on information derived from the writings of others, from which also the probable location of the dam is determinable.

The writer is indebted to Mr. F. C. Calkins, of the United States Geological Survey, for suggestions and criticism.

As long ago as 1885 Professor Chamberlin[2] noted a curious phenomenon in the Flathead lake region that he aptly describes as "a series of parallel watermarks of the nature of exceptionally slight terraces sweeping around the sides of the valley and encircling the isolated hills within it, like gigantic musical staves."

In the vicinity of Missoula similar phenomena have been observed by Professor Salisbury[3] and are noted by Douglass[4] who mentions that "in the Missoula and Bitter Root valleys on the mountain sides and along the foothills are level lines or small terraces, evidently shorelines, formed by the dashing of the waves"; and a brief reference to

[1] Published by permission of the Director of the United States Geological Survey.

[2] T. C. Chamberlin, "Administrative Report," *U. S. Geological Survey, Seventh Ann. Rept.*, 1885–86, 78.

[3] Personal communication.

[4] Earl Douglass, *The Neocene Lake Beds of Western Montana*, published by Montana University, 1899, 10, 11.

them is made by Wood[1] who records that "at Missoula . . . . around the mountains a series of beaches or beach lines extend. . . . ."

The photograph of Mount Jumbo (Fig. 1), a well-known landmark at the mouth of Hell Gate Canyon, brings out more plainly than any written statement could the striking horizontality of these parallel lines. The partly melted snow rather emphasizes them;

FIG. 1.—Hell Gate Canyon, Mount Jumbo, from near Northern Pacific dépôt, Missoula.

still when the ground is entirely bare they can be plainly seen from the city, and have been interpreted by some of the pioneer inhabitants as "old buffalo trails." At close range it is difficult to locate definitely any but the more prominent "trails," the highest of which has an elevation above Missoula of 1,000 feet or 4,200 feet above sea (this and the subsequent elevations as given were determined by aneroid).

University Mountain (Fig. 2), the opposite sentinel of the Hell Gate, exhibits on its western slopes a series of "trails" that are

[1] Herbert R. Wood, "Glaciation in Western Montana," *Science*, XX (1902), 162.

clearly seen to be a continuation of those of Jumbo. From here they may, with many interruptions, be traced to the south along the eastern slopes of the Bitter Root Valley as far as Skalkaho Creek. Again, similar horizontal lines may be seen on the valley's western slopes north of Lo-Lo Fork in situations nearly free from timber. South of Lo-Lo Fork, if they exist, they are obscured by the forest clothing the foothills of the Bitter Root range. Elsewhere, in the

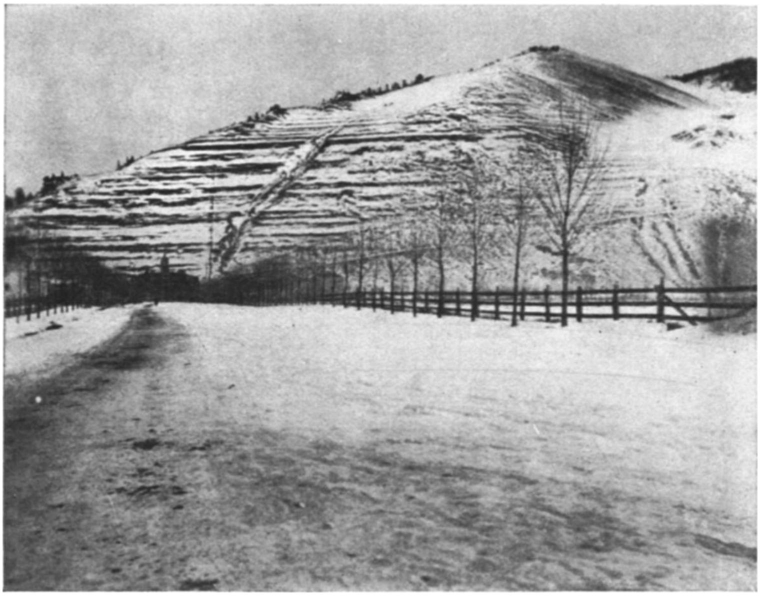

FIG. 2.—University Mountain, from University Avenue, Missoula.

northern slopes of the Missoula Valley below the city of Missoula, and of the Jocko Valley near the Flathead agency, similar "trails" have been noted from a distance. Farther down along the main Clark Fork Valley the slopes are steeper and rocky, and to a great extent timbered. Here the "trails," if they exist, have apparently not as yet been seen, but certain phenomena of this region, as will appear later, may have an intimate relation to them. From unpublished observations of Mr. F. C. Calkins in this area it appears that in the valley of Vermilion Creek an extensive gravel flat trenched by the stream is found at 4,000 feet (aneroid) elevation, and that similar but less extensive deposits are developed at about the same elevation in small canyons opening into the Clark Fork Valley between Vermilion Creek and Thompson Falls.

East of the town of Stevensville a chain of rounded hills projects westward some 5 or 6 miles into the Bitter Root Valley as a spur from its eastern wall. This spur as a whole descends gradually from an elevation of 6,500 feet to about 3,600 feet where its steeply tilted quartzites disappear beneath the horizontally bedded clays, sands, and gravels that form the valley terraces or "bench lands," which bear a

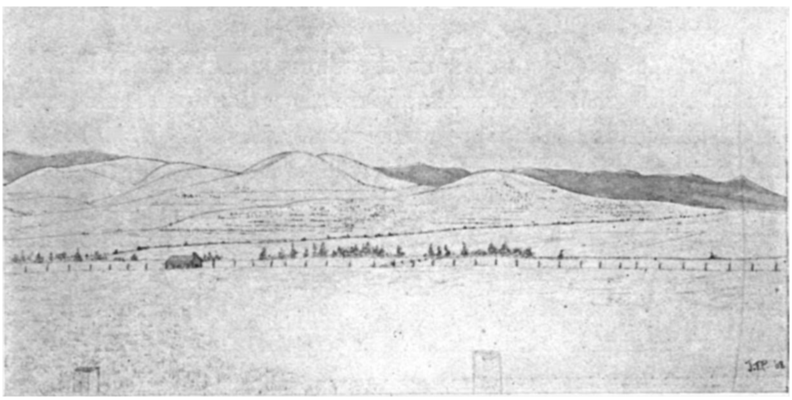

FIG. 3.—Cowell buttes, looking southeast from sec. 6, tp. 9, N.—19 W. Montana Mer., showing the horizontal "trails" marked by rows of trees and shrubs.

thin, clayey, fertile soil that as a rule is sharply defined from the underlying gravel. The two symmetrically rounded outer knobs of this spur are locally designated the Cowell buttes (Fig. 3). The westernmost or first butte attains an elevation of 4,450 feet; the second butte 4,750 feet, while the saddle between is 4,250 feet above sea. The "trails" are well developed on the north and northwest slopes of these buttes; the one at 4,200 feet elevation, above which they apparently fail, is comparatively prominent and its cross-section resembles that of a neglected road grade. The upper bank is broken down but still definable, and the "road bed" eight or ten feet wide merges gradually with the steeper slope below. The sandy soil of this "road bed" is much deeper than that of the slope above and contains numerous subangular to smooth rounded pebbles of quartzite that in the slopes above are wanting. These pebbles range in size up to four or five inches in diameter and, together with larger masses of quartzite associated with them and possessing rounded edges, are undoubtedly waterworn. Among them no pebbles of a material differing from the quartzite bed rock of the immediate vicinity are found. This "trail" can be easily followed around the north slopes of the buttes, tracing a deep re-entrant angle as it curves around the head of the ravine leading north from the saddle. Here the pebbly deposit gives place to a more extensive one of fine, slightly yellowish, quartz sand, that in one place has been channeled by a rain gully to a depth of eight or ten feet.

Below the 4,200-foot contour the slopes exhibit a succession of parallel trails, exact counterparts apparently of those of Mount Jumbo, except that many of them are conspicuously marked by rows of trees and shrubs. One at 3,700 feet elevation is more than ordinarily prominent. It might at one place be easily mistaken for an abandoned wagon-road along which a row of trees had been set. Its cross-section is similar to that of the one at 4,200 feet, but of larger proportions, the "road bed" twelve to fifteen feet wide being likewise formed of a deeper soil than is found upon the adjacent slopes, containing waterworn pebbles and quartzite fragments.

Just below this contour the quartzite disappears beneath the incoherent sediments of the "bench lands" upon which the series of "trails" still continue to be faintly exhibited down nearly to the river's flood plain.

Douglass[1] describes these benches as beds of sand, gravel, and volcanic ash of Miocene age in part. Remnants of the "trails" are not only preserved upon open slopes of this easily eroded material, but upon the sides of the ravines that dissect it, showing that time since the "trails" were formed has been too brief for any material alteration of the topography by erosion.

On the northern slope of the first butte at about 4,100 feet elevation a large subangular bowlder of gneissoid granite rests upon the surface. It has a volume of perhaps five cubic yards. Several similar bowlders have been noted in the neighboring basin of Three-Mile

[1] Earl Douglass, "A Geological Reconnaissance in North Dakota, Montana, and Idaho, etc.," *Carnegie Mus. Annals*, V (1909), 264, 265.

Creek, and elsewhere in the eastern half of the Bitter Root Valley but in no case at a greater elevation than that recorded.

These bowlders are clearly seen to be erratics, not only from their haphazard distribution, but from the fact that their parent rock is not to be found anywhere in their vicinity nor even in the mountains that form the valley's eastern wall from Skalkaho Creek north.

A strikingly similar rock is, however, the prevailing type of the opposite Bitter Root range.[1]

South of Hamilton in front of the canyons of Lost Horse, Rock, and other creeks heading in this range, moraines extending down to 4,000 feet elevation are found.[2] It is perhaps needless to add that elsewhere the Bitter Root Valley has not been glaciated.

The foregoing phenomena as a whole seem explainable only as the records of an extinct lake or sea. The old "buffalo trails" are the existing remnants of its wave terraces. Its high level was approximately 4,200 feet above sea. At this stage the site of the present city of Missoula was 1,000 feet under water, and glaciers from the Bitter Root range south of Hamilton reached the lake, setting bowlder-laden icebergs afloat upon it. One of these bergs grounded on the prominent cape formed by the Cowell buttes.

During the lake's halt at this level its waves worked considerable fine material into the head of the small bay or cove between the buttes, the remnant of which is still to be found in the upper course of the ravine descending from the saddle. Sediments that settled from this lake are believed to be the main source of the soil referred to on p. 378, to which the agricultural value of the "bench lands" is due. The gravel flats observed by Mr. Calkins in some tributary valleys of the Clark Fork are explainable as delta deposits in a lake. The lake receded gradually, recording many brief halts and a comparatively long one at 3,700 feet.

Douglass[3] suggests "that the water cut with comparative rapidity through its barrier in geologically recent times."

[1] Waldemar Lindgren, "A Geological Reconnaissance across the Bitter Root Range and Clearwater Mountains in Montana and Idaho," *Professional Paper, U. S. Geol. Survey*, No. 27, 42–47.

[2] *Ibid.*, 51–55, and Plates I and X.

[3] Earl Douglass, *The Neocene Lake Beds of Western Montana*, published by Montana University, 1899, 11.

In order to understand the problem of the locality of the dam it is necessary to glance briefly at the topography of northwestern Montana and the adjacent panhandle of Idaho. From the map (Fig. 4) it appears that that portion of Montana west of the continental divide

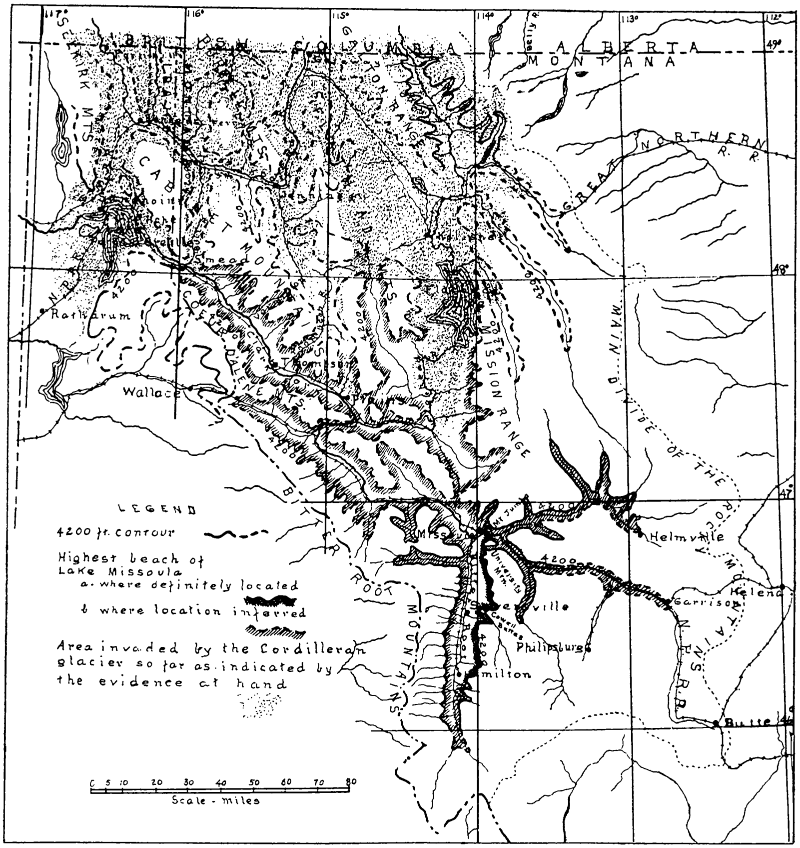

FIG. 4.—Map of northwestern Montana and adjacent portions of Idaho compiled from the U. S. General Land Office maps of Idaho and Montana, topographic sheets of the U. S. Geological Survey, etc.

is largely occupied by an irregular depression, drained by Clark Fork of the Columbia River. If this depression were filled with water to the 4,200-foot contour, the lake formed would be effectively imprisoned on the east and south by the main divide and on the southwest by the Bitter Root and Cœur d'Alene mountains, but to the northwest no continuous barrier exists, a partial one only being afforded by the detached Cabinet, Flathead, and Galton ranges. Between the latter and the continental divide the valley of the upper Flathead River at the 49th parallel sinks slightly below the given plane, and continues, as a depression (the Rocky Mountain trench of Daly),[1] a great distance northwest into British Columbia.

Between the Galton range and Cabinet Mountains is a considerable area which, although partly occupied by the Flathead Mountains, affords two broad passes through which the water would escape to the Kootenai Valley. South of the Cabinet Mountains, the Clark Fork Valley is depressed at the Idaho-Montana boundary 2,100 feet below the 4,200 level. At this point the valley is rather constricted, its cross-section showing a width of three miles near the river level, and about seven miles at 4,200 elevation.

Of special interest to the problem at hand are three north-south depressions that join the Clark Fork and Kootenai valleys. The largest and most important of these is the Pack River or Kootenai Pass through which the Great Northern Railway crosses from Bonners Ferry on the Kootenai to Lake Pend d'Oreille. It is a rather broad, deep valley whose highest point is about 150 feet above lake Pend d'Oreille and is in reality, as shown by Calkins,[2] a part of the Purcell trench, a depression extending northward 200 miles beyond the 49th parallel.

The two smaller trenches cross the Cabinet Mountains east of this one, the Bull Lake trench[3] affording an easy pass with only 700 feet climb, between Smead on the Clark Fork and Troy on the Kootenai, and, farther east, a depression crossing the same mountains between Plains and Jennings. From the foregoing it appears that at the present time a barrier of sufficient height across the depressions just described would restrain a lake in the drainage basin of the Clark Fork, whose waves would terrace the 4,200-foot contour.

This would also be the case in Pleistocene time if the physiography

[1] Reginald A. Daly, *The Nomenclature of the North American Cordillera between the 47th and 53d Parallels of Latitude, Geog. Jour.*, XXVII, No. 6 (1906), 596–98.

[2] F. C. Calkins, "A Geological Reconnaissance in Northern Idaho, and Northwestern Montana, *Bull. U. S. Geol. Survey*, No. 384 (1909), 16.

[3] *Ibid.*, 15.

of this region was then the same as now. This is for the purposes of argument assumed to be essentially true, such crustal warping and modification of the surface by erosion as have occurred during or since that time being, as indicated by the evidence at hand, insufficient to have seriously altered the topography of this region.

The evidence of icebergs, together with the apparent recency of the lake and the variable height of its surface, connect this lake with the glacial period, and readily lend themselves to the suggestion that its dam was of ice.

Bailey Willis has suggested that this was a Pleistocene lake dammed by a glacier.[1] Many years ago Professor Chamberlin conceived the idea of a glacial dam and furthermore tentatively suggested that its location was in the Pend d'Oreille region with outflow by way of Spokane.[2]

While there has been some local glaciation in the Cœur d'Alene and Cabinet mountains[3] it is evident that these small glaciers were inadequate to have themselves formed the dam, although they may have aided in its production.

That British Columbia was formerly buried under a vast accumulation of ice, generally referred to as the Cordilleran ice-cap, has been made known by the writings of Dawson and others. It appears that south-flowing portions of this ice-cap were even at the 49th parallel of great depths.[4] Its margin was markedly lobate, south-flowing tongues having occupied every large valley that crosses the International Boundary between the Cascade Mountains and the continental divide. To this ice invasion the "trenches" characteristic of this region owe, in a certain measure, their form and fairly constant depth.

While the limits of these great valley glaciers which crossed the boundary west of the Idaho panhandle are fairly well known, knowledge of those east of that point is more or less fragmentary. Some

[1] Earl Douglass, *The Neocene Lake Beds of Western Montana*, published by Montana University, 1899, 11.

[2] Personal communication.

[3] F. L. Ransome and F. C. Calkins, "The Geology and Ore Deposits of the Cœur d'Alene District, Idaho," *Professional Paper, U.S. Geol. Survey*, No. 62, 15, 57; and F. C. Calkins, *op. cit.*, 15.

[4] R. A. Daly, *Can. Geol. Survey, Summary Report*, 1903, 93; *ibid.*, 1904, 95.

idea of the great depth near the 49th parallel of the one that flowed south through the Rocky Mountain trench may be gained from the fact that here it overflowed eastward across the continental divide through Ahern and other passes at the head of Belly River.[1]

The eastern or upper Kootenai Valley held another great south-flowing glacier.[2] At Kalispell, about sixty-five miles south-southeast from the boundary at the point just referred to, the ice was 3,000 feet deep, or its surface nearly 6,000 feet above sea, and came from the north-northwest.[3]

This lobe, probably reinforced by that of the upper Flathead Valley, flowed southward across the Flathead lake region, reaching, as indicated by the observations of Professor Elrod,[4] to the Jocko Valley. A deep glacier flowed south through the Purcell trench, extending at least to the southern end of Lake Pend d'Oreille.[5] At the north shore of this lake, ice is shown by Calkins[6] to have been about 2,500 feet deep.

The same author has also noted the glaciation of Clark Fork Valley above Lake Pend d'Oreille in the vicinity of Bull River,[7] and his observations, with those of Wood,[8] indicate the ice to have been at least 2,000 feet deep. Bull Lake trench probably supported another deep ice-stream[9] that may have been a branch from the Purcell lobe at Bonners Ferry. There is also evidence to indicate that south-flowing ice occupied the Kootenai Valley above Libby,[10] and also the Plains-Jennings depression.[11]

[1] G. E. Culver, "Notes on a Little-known Region in Northwestern Montana," *Trans. Wis. Acad. Sci.*, VIII (1891), 204.

[2] R. A. Daly, *Can. Geol Survey, Summary Report*, 1904, 95.

[3] R. D. Salisbury, "Glacial Work in the Western Mountains in 1901," *Jour. of Geol.*, IX, 724.

[4] M. J. Elrod, "The Physiography of the Flathead Lake Region," *Bull. University of Montana*, No. 16, 202.

[5] T. C. Chamberlin, *Seventh Ann. Rept. U. S. Geol. Survey*, 1888, Plate VIII, 178, 179, and Fig. 15; *ibid.*, "Administrative Report," 1885–86, 78; and Bailey Willis, "Changes in River Courses in Washington Territory, Due to Glaciation," *Bull. U. S. Geol. Survey*, No. 40, 8.

[6] F. C. Calkins, *op. cit.*, 31.

[7] *Ibid.*

[8] H. R. Wood, "Glaciation in Western Montana," *Science*, XX (1902), 162.

[9] F. C. Calkins, *op. cit.*, 31, and unpublished field notes.

[10] R. D. Salisbury, *op. cit.*, 723, 724.

[11] H. R. Wood, *loc. cit.*

It appears then that escape of the water through the more northerly passes or by way of the lower Kootenai was effectually blocked by ice-barriers of much more than the necessary height.

One of the very largest of these lobes flowed south through the Purcell trench and dammed the only remaining avenue of escape, the Clark Fork Valley. From 7,300 feet elevation at the 49th parallel the glacier's surface sloped down to about 4,200 feet here, where it forced the lake to seek its outlet.

While the vagueness and close spacing of most of the lower beaches seem to depend on the inconstant level of an ice-dam that formed one wall at least of the outlet, the more prominent ones, indicating constancy of level for a relatively long period, suggest that the outlet may at times have been a col in some opposing spur from the Cœur d'Alene Mountains. Until the ice, by rising, should invade such an outlet, or by sinking below it should capture its flow, the water level would be comparatively stable.