EARLY PLEISTOCENE GLACIATION IN IDAHO

By Clyde P. Ross

ABSTRACT

On and near Railroad Ridge, Custer County, Idaho, there are deposits of unconsolidated material, believed to be of glacial origin, which are out of harmony with the present topography. The evidence suggests that this material is the product of glaciation in early Pleistocene, possibly Nebraskan time and indicates that at that time the country was far less rugged than at present. Valley cutting of the order of 1,400 feet took place in the interval between this early glaciation and Wisconsin time, when the glacial cirques and U-shaped valleys that are prominent features of the present topography were formed. This deep cutting is in marked contrast with the erosion of 100 feet or less that has occurred in Recent time.

Similar though less complete evidence of ancient glaciation followed by deep erosion is known on Loon Creek, farther north, and on the Little Wood River, farther south. All three localities are close to the highest peaks in Idaho. Evidence of similar conditions in the Pleistocene epoch has been found by other investigators in Montana, Wyoming, and perhaps Washington. Although two widely separated periods of glaciation are recorded in northern Idaho, neither appears to be as old as that here described.

FOREWORD

It has long been known that the mountains of central and northern Idaho bear much evidence of former glaciation. The glacial phenomena commonly observed are confined to existing valleys and were doubtless produced late in the Pleistocene epoch. Recent work indicates that there was in addition a much earlier glaciation, which preceded the development of the present topography. The best evidence for this now known is found on and near Railroad Ridge, in unsurveyed Tps. 9 and 10 N., R. 16 E., south of the Salmon River, in the southern part of Custer County, but deposits that may have been produced during the ancient glaciation have been noted on Loon Creek, farther north, and on the Little Wood River, in Blaine County, farther south. It may be significant that all these localities, the only known places where there are traces of the ancient glaciation, are near the highest summits in Idaho.

RAILROAD RIDGE

DESCRIPTION

The smooth, almost level top of Railroad Ridge contrasts so sharply with the ragged pinnacles around it that it has long been an object of local interest. This ridge and much of the Custer quadrangle, in which it lies, were visited during the summer of 1928 by the writer and his assistants, Robert R. LeClercq and William D. Mark, in the course of a geologic study of this part of Idaho.

Railroad Ridge was so named because of the fancied resemblance of the ridge, viewed from a distance, to a railroad grade. Plate 17 shows the general appearance of the ridge, and, by way of contrast, the cirque cliff known as the Chinese Wall, a short distance to the west. As can be seen from Plate 16 the ridge trends nearly east, and its highest and smoothest part is 2 miles long and has an average width of somewhat less than half a mile. This portion slopes from an altitude of 10,400 feet above sea level near its west end to 9,400 feet at its east end. It therefore has an average grade of 10 per cent, which appears flat when contrasted with the cliffs and steep slopes on every side. From the high west end of the ridge there is an abrupt descent of over 1,400 feet to the lake at the head of Livingston Creek, and on the south there is a comparably sharp drop into Jim Creek. On the east and north the contrast with the surrounding area is less striking, as much of the country here is a dissected plateau whose surface lies more than 9,500 feet above sea level, as shown on Plate 16. (See also pl. 18, *A*.) The streams, however, are rapidly cutting into the plateau, and two of them, Lake and Silver Rule Creeks, are already cutting into Railroad Ridge. Plate 18, *A*, shows the extent to which Silver Rule Creek is incised below the plateau level. Much of the cutting of these streams took place in Pleistocene time, for the valleys of all the larger streams, including those just mentioned, have been glaciated in their upper reaches, as shown in Plate 19.

The top of Railroad Ridge is only about 400 feet below the highest peak in its immediate vicinity and about 1,400 feet below the summit of Castle Peak, 7 miles to the south. Castle Peak is the highest peak in the Custer quadrangle and one of the highest in Idaho, being exceeded in altitude only by Mount Hyndman, 12,078 feet, which is 30 miles southeast of it, and by a few peaks of intermediate height along the range between these two.[1]

[1] Since this was written Lee Morrison, of the U. S. Geological Survey, has found that one of the peaks in the Lost River Range is nearly 600 feet higher than this.

Railroad Ridge is remarkable not only for the topographic characteristics and relations sketched above but also for its geologic composition. Plate 16 shows the geology of this ridge and its vicinity. The boundaries on this map at a distance from the ridge are subject to revision in detail, but the essential features are correctly shown. A large area on Railroad Ridge and smaller areas both north and south of it are mapped as glacial detritus. As will be seen below, the proof of the glacial origin of this material is not absolute, but it is regarded as highly probable. The boundaries of these areas were traced with care, but it is possible that there are additional small areas. Numerous erratic boulders on Slate and Livingston Creeks, composed mainly of granitic rock, suggest the former presence of morainal deposits at high levels. Boulder Creek and the region south of it were not reached during the present study, but in the summer of 1929 Thomas H. Hite found extensive deposits of similar detritus on the ridges near the mouth of Boulder Creek and south of it.

Plates 17, *A*, 18, *B*, and 19, *A*, show that the deposit on Railroad Ridge is coarse, poorly sorted, and poorly rounded. Nearly all of it is composed of granitic rock like that at the head of Boulder Creek mapped on Plate 1. Near the base fragments of the rocks underlying this great mass of débris have been incorporated in it, but even here they are subordinate in size and amount to the granitic rock. The deposit is sufficiently compacted to form slopes steeper than would be maintained in loose gravel but contains little or no cementing material. The granitic rock composing most of the fragments has been sufficiently weathered to roughen the surface, but most of the boulders are firm and fairly fresh. The material composing the smaller detached masses is essentially similar to that in the main body described above. In all exposures noted there is little variation either in average coarseness or in degree of rounding of the material.

Railroad Ridge was referred to by Umpleby[1a] as one of the remnants of a postulated peneplain which he considered to be of Eocene age. This assumption, however, was based on observation from a distance of over 12 miles. The description of the ridge given above shows clearly that its surface can not be as old as Umpleby supposed.

AGE

There can be little doubt that this material is of early Pleistocene age. Its lack of consolidation, its freshness, and the fact that it is spread, in large part, over a surface carved on tilted lava and tuff beds of Tertiary (probably Miocene) age all indicate that it is geologically young, probably not older than Pleistocene. It appears from physiographic studies elsewhere in the general region, already presented in outline [2] and to be further discussed in later papers, that a mass of coarse detritus so situated can not be older than late Pliocene, but its lack of accord with modern drainage lines shows that it is older than the present erosion cycle. As the upper reaches of all the larger stream valleys in the high mountains show abundant evidence of late Pleistocene (Wisconsin) glaciation it is evident that detritus formed earlier than these valleys must be older than that formed in Wisconsin time. Direct evidence that the material is older than the Wisconsin glaciation is furnished by the fact that it forms the upper part of the glacial cirque wall near the head of Silver Rule Creek, as can be seen in Plate 19, *A*. Similarly the detrital mass is truncated by the upper part of the valley of Jim Creek, which has a cirque at its head and has the typical U-shaped cross section of a glaciated valley, as is evident from Plate 19, *B*.

ORIGIN

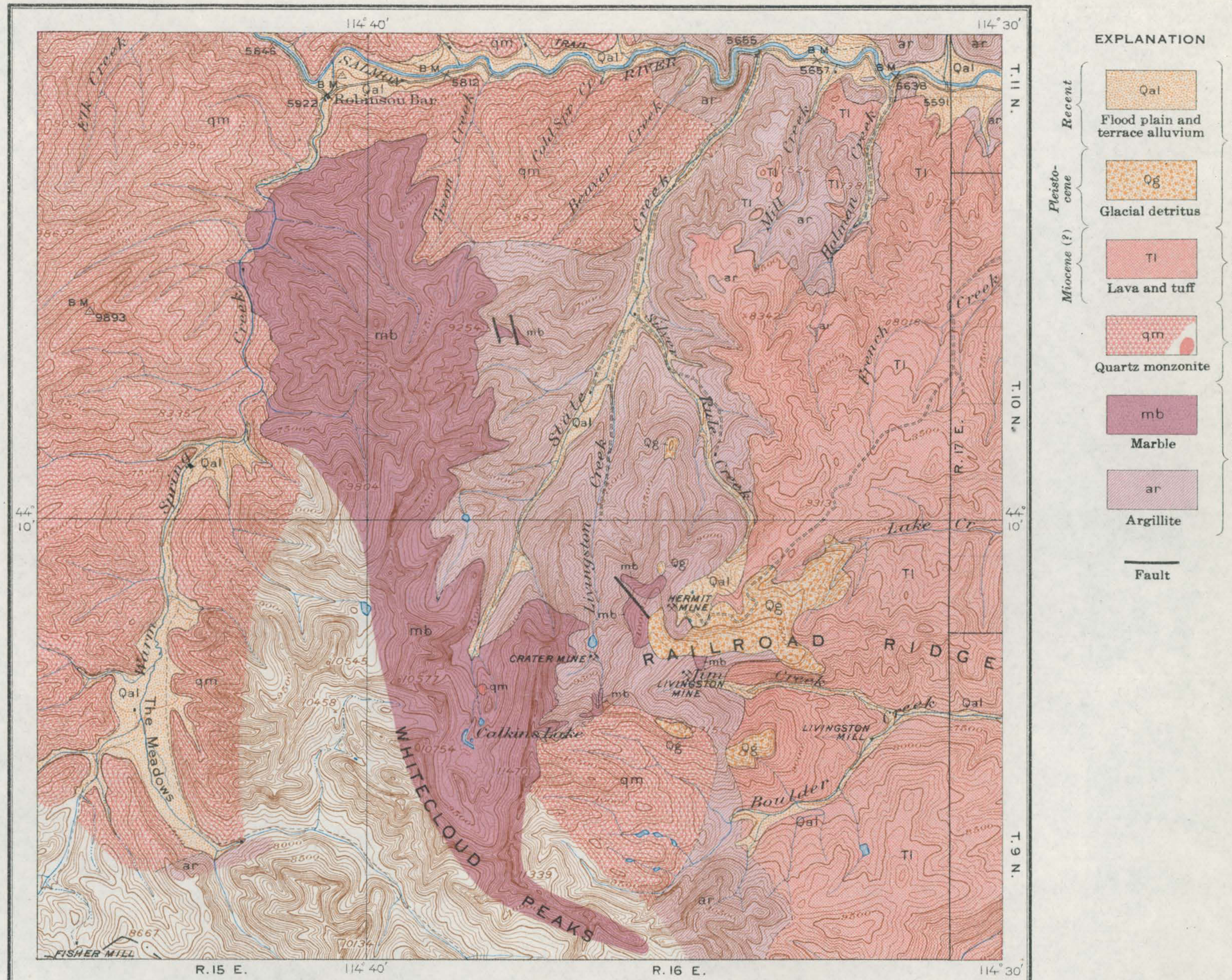
There is no positive way of distinguishing between many glacial deposits and the deposits of a torrential stream from the appearance of the material alone. The hypothesis of glacial origin fits the general relations of this material, however, far better than any other. The former presence in this location of a stream of adequate size and power to lay down such a deposit is almost inconceivable. Furthermore, the shape of the surface on which the material lies, the apparent lack of space for a drainage basin of adequate size at altitudes above the present position of the material, and the strictly localized source of most of it, all argue against a fluviatile origin.

The detritus lies on a gently inclined surface that shows no evidence of having been a part of a stream valley. Along the north side of Jim Creek and at the west end of Railroad Ridge the deposit of detritus is thin. Here it is evident that the surface on which this material was laid down is irregular in detail and contains small shallow undrained hollows. This surface is now covered with soil and fragmental material derived in part from the mass of detritus which lies above it, in part from the weathering of the bedrock, which is here mainly slate. Hence no opportunity was afforded at any locality visited to determine whether the bedrock surface is polished or grooved by a glacier.

Not only does the shape of the surface under the detritus on Railroad Ridge differ from that of a stream valley but the relations of the several patches of this material to one another and to the existing topography seem to preclude a fluviatile origin. Inspection of Plate 16 indicates that the country at the time the detritus was deposited was rolling and had only about

[1a] Umpleby, J. B., Some ore deposits in northwestern Custer County, Idaho: U. S. Geol. Survey Bull. 539, p. 15, 1913.

[2] Ross, C. P., Salient features of the geology of south-central Idaho: Washington Acad. Sci. Jour., vol. 18, p. 268, 1928.



Base from U. S. G. S. topographic map of Custer quadrangle

Geology by C. P. Ross

RECONNAISSANCE GEOLOGIC MAP OF THE AREA AROUND RAILROAD RIDGE, CUSTER COUNTY, IDAHO

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 Miles

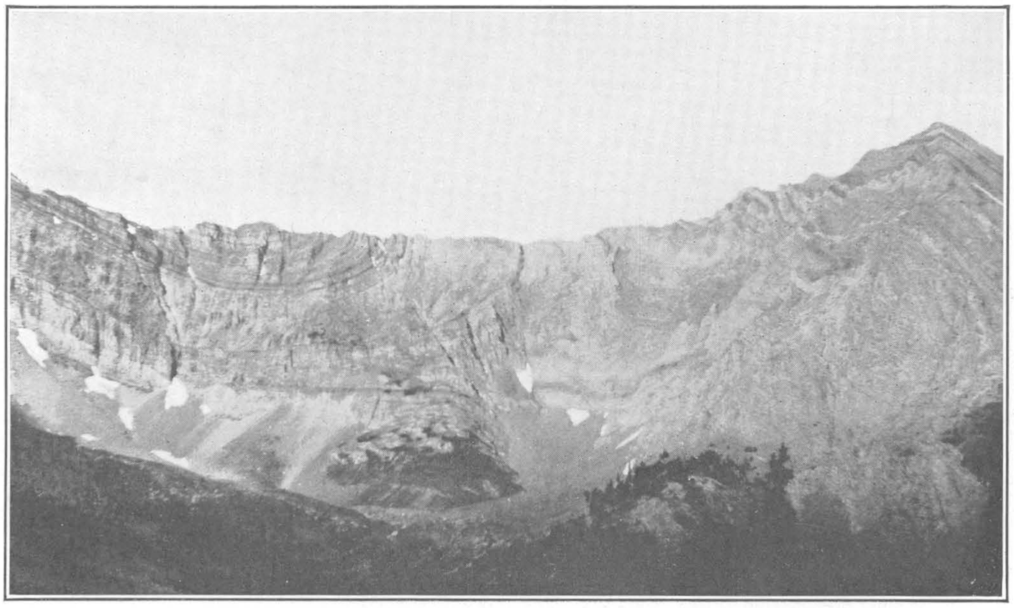
Contour interval 100 feet.

Datum is mean sea level.

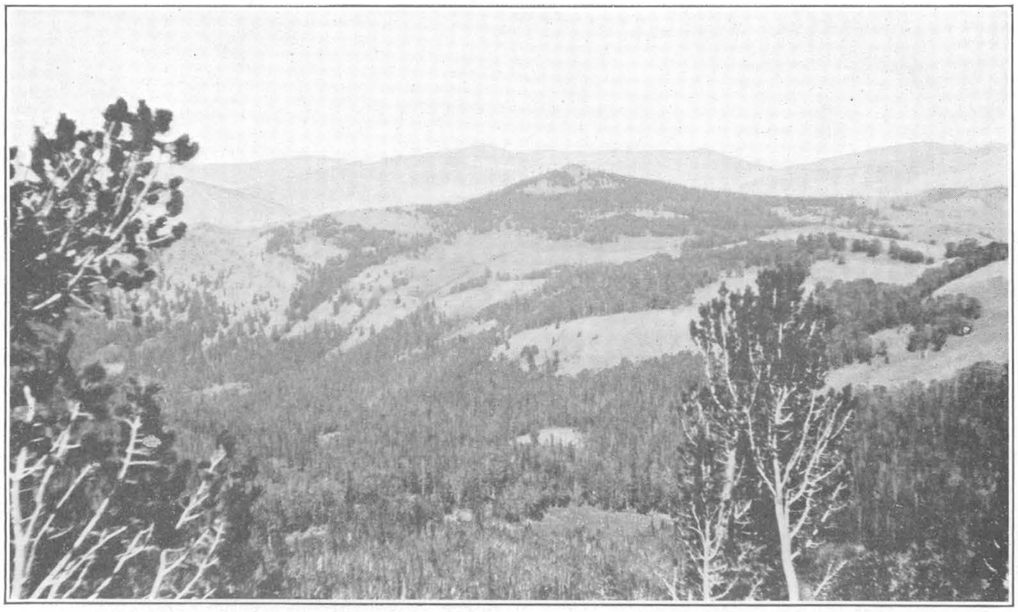
1929

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

A. RAILROAD RIDGE, IDAHO, LOOKING EAST FROM A POINT NEAR THE HIGHEST PART OF THE RIDGE

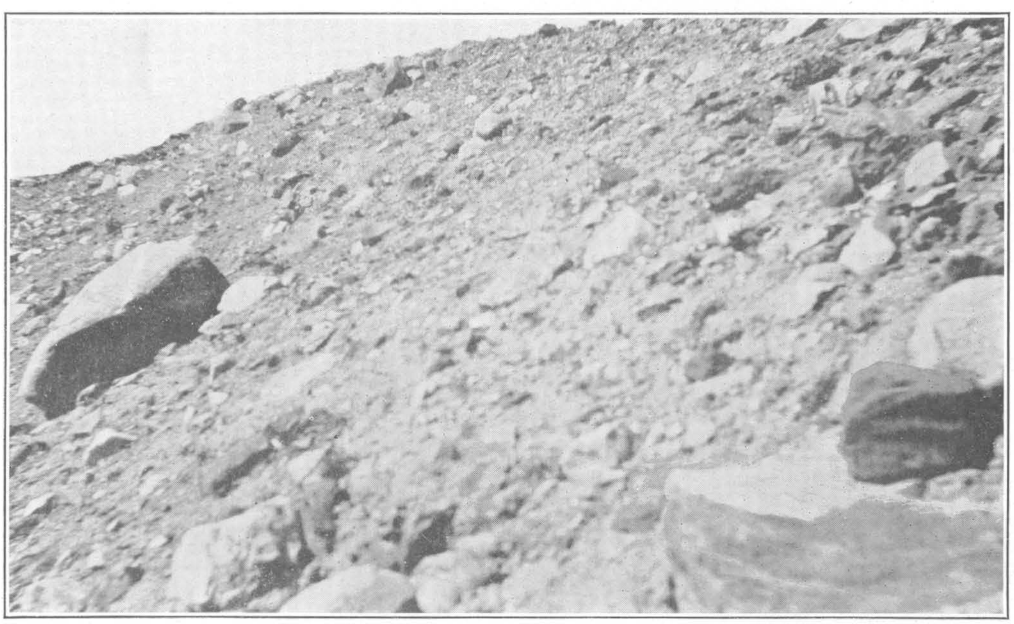


B. THE "CHINESE WALL" AT THE HEAD OF LIVINGSTON CREEK, IDAHO



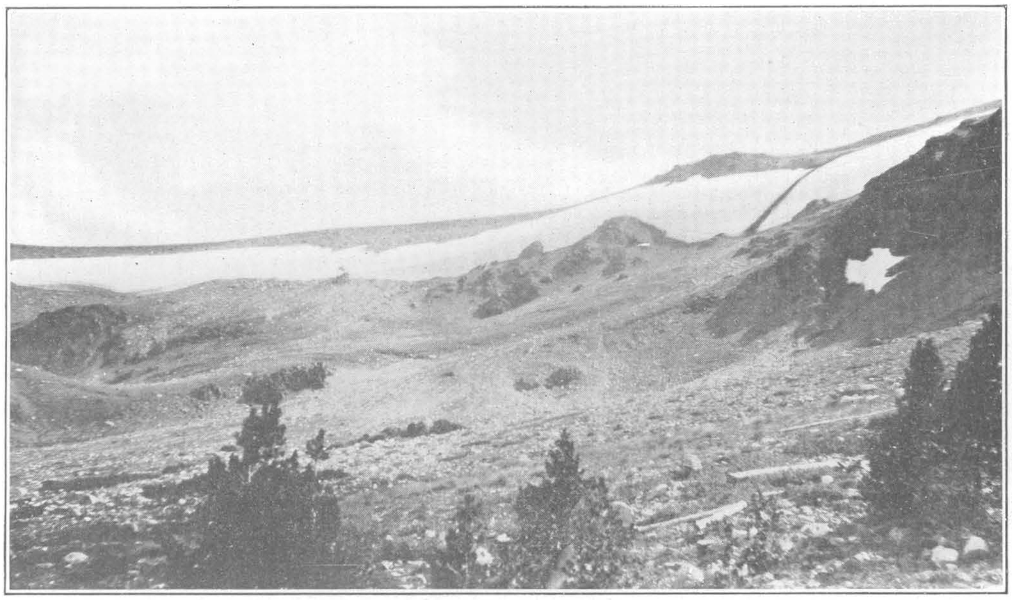
A. THE DISSECTED PLATEAU CARVED ON TERTIARY VOLCANIC ROCKS AND THE BASIN AT THE HEAD OF SILVER RULE CREEK, IDAHO

View northeast from a point just below the Hermit mine.

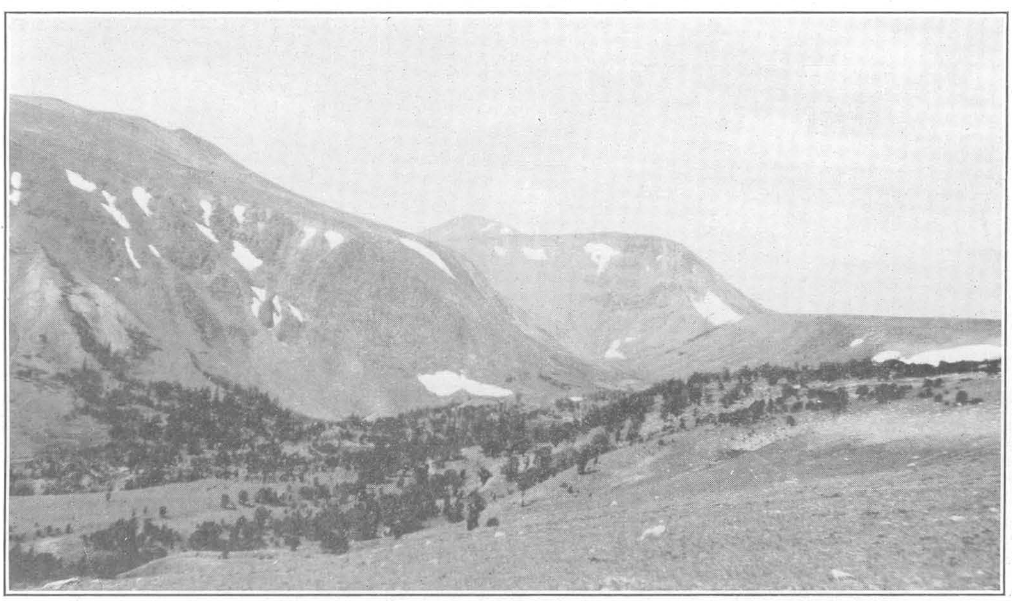


B. CLOSE VIEW OF THE DETRITUS COMPOSING RAILROAD RIDGE, IDAHO

Exposure is near the top of the ridge east of the Hermit mine.



A. CIRQUE CARVED IN DETRITUS AND PALEOZOIC STRATA AT THE HEAD OF SILVER RULE CREEK, IDAHO



B. THE HEAD OF JIM CREEK, LOOKING WEST FROM A POINT NEAR THE NORTHEAST END OF THE DETRITUS ON RAILROAD RIDGE, IDAHO half as much relief as it has now. In order to present this fact more definitely an attempt is made in Figure 18 to restore the topography as it was at the time the detritus was being deposited. This figure is constructed on the basis of the distribution of the existing remnants of the detrital masses, the shape of the surfaces on which they rest, and the present topography. If possible later deformation is disregarded, it is evident that all parts of the surface not now protected by detritus are relatively lower than they were at the time of deposition. Hence, hills now higher than the existing detritus represent high ground at the time of deposition. This is the principal basis on which contours were interpolated on Figure 18 in areas not now covered by detritus. It is obvious that the detritus has suffered from erosion and was originally more extensive than it is now. Possibly it originally covered much of the area contoured in Figure 18. Its distribution with reference to the contours indicates that there is little correspondence between the location of the portions now remaining and the depressions of the old surface. Obviously the contouring in Figure 18 can not be accurate in detail. It is well within the bounds of possibility that a more pronounced depression existed along or near the course of Silver Rule Creek than is shown in that figure. The patches of detritus remaining on the ridge between Silver Rule and Livingston Creeks may have been deposited on the flanks of such a depression.

In other parts of south-central Idaho that have been studied by the writer there is evidence of minor faulting and of broad-scale uplift in the Quaternary period. The great amount of erosion in the region here considered, indicated by the contrast between the contouring on Figure 18 and that on Plate 16, is probably to be ascribed in part to differential uplift, with consequent rejuvenation of the streams. However, all the deformation of the rocks of which evidence was observed here probably took place long before the deposition of the detrital material under discussion. The Tertiary volcanic strata are warped but not intricately deformed. Hence it is improbable that any crustal deformation that may have taken place subsequent to the formation of the surface which Figure 18 is intended to portray was of such a character as to affect materially the accuracy of the restoration attempted in this figure. It appears from studies here and elsewhere in this general region that in late Pliocene or early Pleistocene time the region had comparatively low relief. Plate 18, *A*, shows a portion of this old surface, now considerably dissected. If due allowance is made for later erosion, this picture may be taken to give an idea of the topog-

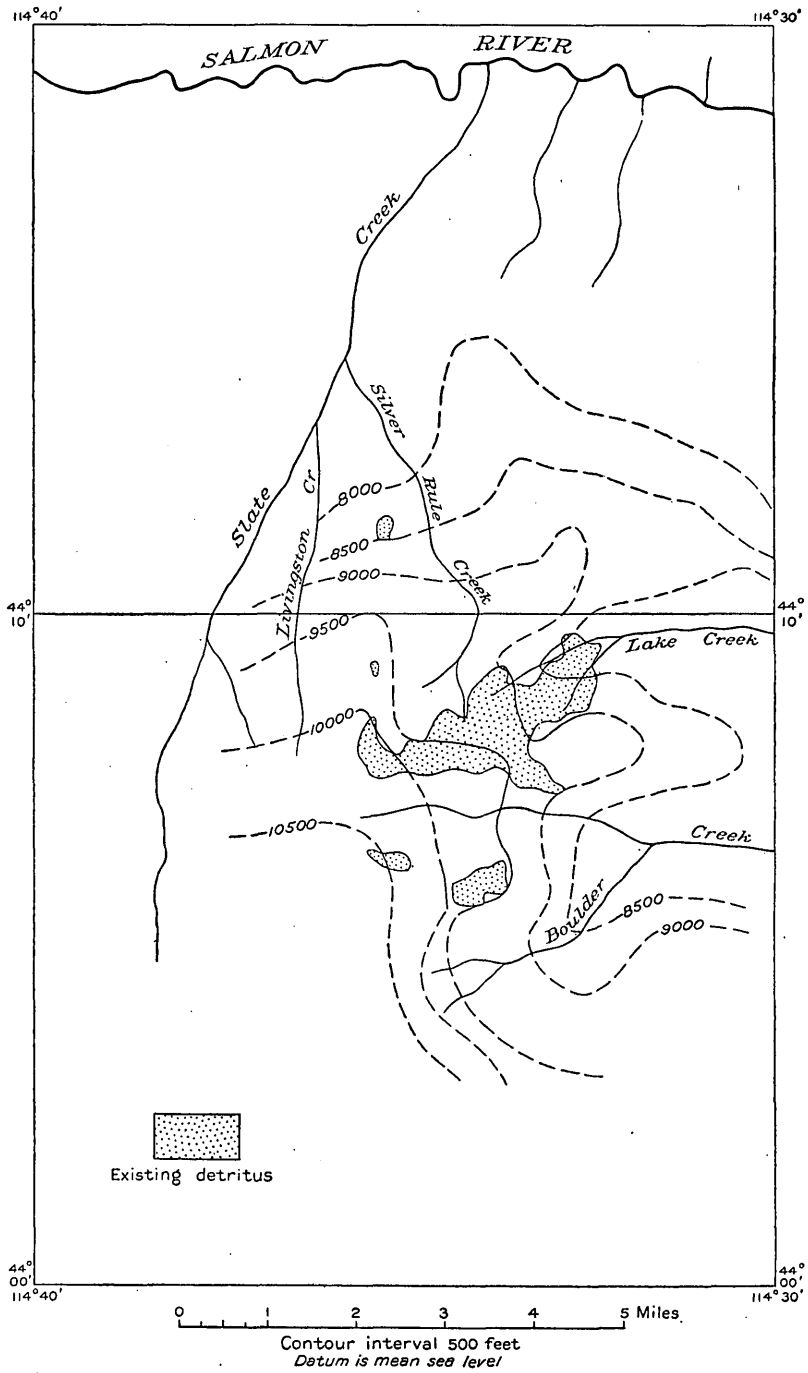


FIGURE 18.—Restoration of the surface on which the detritus on Railroad Ridge, Custer County, Idaho, was deposited

raphy existing at the time the material under consideration was being laid down—that is, the topography diagrammatically contoured in Figure 18.

In general, it appears that the evidence afforded by the apparent shape of the surface on which the detritus was deposited is opposed to the theory that this material was laid down in ordinary streams. The evidence, both as to the general topography before the deposition of this material and as to the details of the shape of the surface that is now being uncovered along the borders of the detrital mass on Railroad Ridge, is much more nearly in accord with the conception of deposition through the agency of glaciation.

Further evidence against the conception of a fluviatile origin is furnished by the apparent lack of a drainage basin of sufficient size to feed a stream competent to transport and deposit so large a mass of gravel as that on Railroad Ridge. So far as can be seen from present exposures this material is unsorted and unstratified. Plate 18, *B*, shows the heterogeneity plainly and is typical of all the exposures seen. Such a mass of unsorted detritus, if of fluviatile origin, would be a fanglomerate and produced by a stream of considerable length and torrential velocity. Except under such abnormal conditions as are furnished by melting glaciers, or possibly by the sudden release of a large body of impounded water, a large stream could be formed only where there was a large area tributary to it. If this unsorted and poorly rounded material is of fluviatile origin, it was probably produced under arid conditions. Such conditions would decrease the area necessary, because the products of erosion would be dumped closer to their source and remain longer than where abundant water was available for transportation. Even under arid conditions, however, the area necessary would seem to be larger than appears to have been available. No other evidence of aridity in this region in early Pleistocene or late Tertiary time is known.

Railroad Ridge is at present one of the higher parts of the region, and the areas in the vicinity that rise above it are of decidedly small extent and the highest are close at hand. In order to conceive of a stream of nonglacial origin competent to deposit the detritus now present on Railroad Ridge it would be necessary to postulate the existence of a topography so different from that of the present time as to tax the imagination. The former presence of such a topography would imply pronounced orogenic movements, of which no evidence was obtained in the examination of this region. Glaciation, however, with its intensive erosion in circumscribed areas, could produce detritus comparable in amount to that under consideration by attack on an area far smaller than would be required by an ordinary stream.

The fact that nearly all the detritus is composed of granitic rock is likewise opposed to the theory of fluviatile origin. It is difficult to conceive of normal stream erosion, under any climatic conditions, being so selective in its action in a region of diverse rocks as to deposit such a mass of almost exclusively granitic gravel. Plate 16 shows that the only probable sources of this material are the rather small exposure south of Railroad Ridge and the large one west and northwest of it, which is part of the Idaho batholith proper. Both this part of the batholith and any detached masses beyond the limits of the geologic map (pl. 16) would seem to be too far away for gravel derived from them to be deposited on Railroad Ridge except under very special and improbable conditions. This objection applies to derivation by either fluviatile or glacial action. Furthermore, derivation from these sources implies a greater difference from existing topography than is probable. Hence the granitic rock south of Railroad Ridge in and near the headwater basin of Boulder Creek is regarded as the only probable source of the detritus. This mass, however, has an area of less than 6 square miles. The fact that this is the only probable source for by far the greater part of the detritus lends support to the argument in the preceding paragraph that there was insufficient area available for the accumulation of such a deposit as that here discussed by the agency of ordinary streams. Also it is surprising, if streams were the agents of accumulation, that tributaries failed to introduce material from the Paleozoic sedimentary rocks that are so abundant on all sides. Some of the detritus is 3½ miles from the edge of the granitic mass. A mountain glacier, however, derives much of its débris from erosion in the cirques at its head and hence would be more selective in its action than a stream with tributaries.

The hypothesis that the detritus on and near Railroad Ridge was derived from a glacier which has its head in the granitic rock near the present head of Boulder Creek is further supported by Figure 18. The highest part of the surface there contoured corresponds to the granitic mass at the head of Boulder Creek. With all due allowance for the inaccuracy inherent in the construction of this figure, this broad relation seems substantiated.

The character of the detritus on and near Railroad Ridge is in accord with the hypothesis of glacial origin, but the present shape of the mass on the ridge is not that of a moraine. The other detached masses have probably suffered too much from erosion for their original shapes to be recognizable. The mass on Railroad Ridge, as can be seen from Plates 17, *A*, and 19, *B*, and less vividly from Plate 16, is remarkably flat and smooth on top. This is the most striking feature of the ridge and suggests the leveling action of water rather than direct dumping from a glacier. Most moraines have irregular surfaces and rounded rather than flat tops. The mass on Railroad Ridge has large lateral dimensions in proportion to its thickness and hence most resembles a ground moraine.

Such moraines, however, have generally more or less hilly or undulating topography. If, therefore, the detritus on Railroad Ridge is of glacial origin, it has probably been somewhat smoothed by running water, possibly in part by water derived from melting of the glacial ice. The long time that has elapsed since its deposition would permit considerable smoothing of the original topography through the agency of weathering. The detached masses of similar material probably originally formed parts of the same plain, although it may be that some of them were parts of separate moraines or outwash plains deposited by the same or near-by glaciers.

LOON CREEK

One of the two other localities in Idaho where similar conditions have been noted is on the west side of Loon Creek near the Boyle ranch, in Custer County, 30 miles northwest of Railroad Ridge. This locality was examined in the course of a geologic study of the Casto quadrangle. The material is essentially similar to that on Railroad Ridge, being poorly sorted and rounded and composed mainly of granitic rock although resting on metamorphosed sedimentary rock. The boulders, which reach 10 feet in maximum diameter, are much more softened by weathering than those on Railroad Ridge. Such material was noted on the slopes of Loon and Trail Creeks up to an altitude of over 7,800 feet, which is about 2,000 feet above Loon Creek at the Boyle ranch, and it now extends down almost to stream level. The conclusion was reached that this detritus is probably a product of glaciation so much older than the Wisconsin that the record of it has been obliterated elsewhere in the vicinity. It appears to have been a moraine or similar body which has been undercut by Loon Creek, causing part of it to slide far down the slope.

LITTLE WOOD RIVER

Westgate [3] in his study of the Hailey quadrangle, which is immediately southeast of the Custer quadrangle, noted indications of glaciation older than that abundantly evident in the higher stream valleys of the region. He cites the presence of erratic boulders as much as 2 feet in diameter on the slopes above the Little Wood River at altitudes of 500 to 700 feet above the stream. Evidently the amount of old detritus remaining here is far less than in the two localities cited above, but in other respects the relations are similar.

SIMILAR CONDITIONS IN NEIGHBORING REGIONS

The localities above cited are the only ones in central Idaho where evidence of pre-Wisconsin glaciation is known, but such evidence has been found by several investigators in western Montana and Wyoming, northern Idaho, and eastern Washington. Alden [4] reports old glacial drift in Glacier National Park 1,000 to 1,300 feet above the bottoms of adjacent valleys. He believes that these valleys, which were themselves glaciated in Wisconsin time, were cut subsequent to the glaciation recorded by the old deposits. Thus conditions in Glacier National Park closely parallel those in the vicinity of Railroad Ridge, here described. Alden also finds evidence of old glaciation followed by 1,000 feet of downcutting in the Gros Ventre Valley, Wyo.[5]

Alden further believes [6] that there is strong presumptive evidence of early Pleistocene glaciation in the northern Rocky Mountains in general and emphasizes the marked erosion in pre-Wisconsin time in Montana in contrast to the comparatively small amount of erosion since then. He states that the depth of post-Wisconsin stream erosion in some of the mountain canyons in the region he describes is as great as 200 feet. Along the upper Salmon River in central Idaho recent downcutting is probably between 50 and 100 feet, partly in alluvium, partly in rock. Lindgren [7] stated that the depth of postglacial erosion by the Snake River on the western border of Idaho was limited to the removal of 300 feet of unconsolidated late Pleistocene sediments and an insignificant deepening of the early Pleistocene rock-cut channel.

Blackwelder [8] found similar evidence of old glaciation in western Wyoming and adjoining parts of Idaho, especially in and near the Teton Range and along the Buffalo Fork of the Snake River. This consists of glacial deposits, which he calls the Buffalo drift. Canyons have subsequently been cut through this drift and 200 to 1,000 feet into the underlying bedrock. The topography has been so much modified since the old glaciation as to obliterate most traces of morainal topography and to make it uncertain whether the glaciers were of valley type or parts of an ice cap. Blackwelder also found glacial drift of an intermediate stage which he designated the "Bull Lake stage." This drift, he thought, might correspond either to the Iowan or the early Wisconsin drift of the Mississippi Valley.[9]

[3] Umpleby, J. B., Westgate, L. G., and Ross, C. P., Geology and ore deposits of the Wood River region, Idaho: U. S. Geol. Survey Bull. 814 (in press).

[4] Alden, W. C., Pre-Wisconsin glacial drift in the region of Glacier National Park, Montana: Geol. Soc. America Bull., vol. 23, pp. 687-708, 1912. Alden, W. C., and Stebinger, Eugene, Pre-Wisconsin glacial drift in the region of Glacier National Park, Mont.: Geol. Soc. America Bull., vol. 24, pp. 529-572, 1913.

[5] Alden, W. C., Landslide and flood at Gros Ventre, Wyo.: Am. Inst. Min. and Met. Eng. Tech. Pub. 140, pp. 12-13, 1928.

[6] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 405-423, 1924; Pre-Wisconsin glaciation of northern Rocky Mountains [abstract]: Pan-Am. Geologist, vol. 43, pp. 371-372, 1925.

[7] Lindgren, Waldemar, The gold belt of the Blue Mountains of Oregon: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 2, p. 585, 1901.

[8] Blackwelder, Eliot, Post-Cretaceous history of the mountains of central western Wyoming, pt. 3: Jour. Geology, vol. 23, pp. 328-333, 1915.

[9] See also Alden, W. C., Glaciation and physiography of Wind River Mountains, Wyoming [abstract]: Washington Acad. Sci. Proc., vol. 16, p. 73, 1926. Alden thinks that Blackwelder's "Bull Lake" stage may correspond to the Iowan stage of glaciation in the Mississippi Valley.

Anderson[10] has recently discussed the evidence of an early glaciation in northern Idaho. He thinks that this glaciation was more powerful than the last one and effected marked drainage changes and much erosion. He pictures the earlier glaciation as effected by thick glaciers which eroded deeply in valleys still existing, and he finds no such evidence of deep erosion subsequent to the early glaciation as has been noted in Montana and south-central Idaho. Also Anderson follows Bretz[11] in considering the earlier glaciation he describes as of either Iowan or early Wisconsin age.

Alden[12] regards the earliest glaciation in the Glacier National Park region as marking the beginning of Pleistocene time and probably contemporaneous with the Nebraskan stage of continental glaciation. In view of the similarity in conditions it is presumed that the early glaciation in south-central Idaho was contemporaneous with that in the Glacier Park region. Presumably the differences indicated for the early glaciation described by Anderson show that it was more recent than that described above.

The two better known stages of glaciation in eastern Washington[13] were of continental type and were probably more recent than the earliest glaciation in northern Montana and south-central Idaho. Leverett,[14] however, found glacial till at Cheney, southwest of Spokane, and also in the Puget Sound region, which he thought might be as old as Kansan. Perhaps this old till is to be correlated with that in south-central Idaho described above.

CONCLUSIONS

The conclusion seems inescapable that in early Pleistocene or late Pliocene time the topography of south-central Idaho was far less rugged than that of the present day or even of late Pleistocene time. Later erosion has incised valleys in the high country to depths of more than 1,000 feet, in striking contrast to the downcutting of a few score feet generally supposed to have taken place in the region since the Wisconsin glaciation. In some way considerable deposits of coarse, poorly sorted detritus were laid down in several localities in the higher parts of the region before the extensive downcutting took place. The available evidence indicates that these deposits are of glacial origin. Some, at least, were probably modified by the action of fluvioglacial water. The most probable alternative hypothesis is that they are products of torrential streams under more or less arid conditions, but this involves such profound orogenic and physiographic changes since the material was laid down as to be much less acceptable than the hypothesis of glaciation. The fact that similarly ancient glaciation followed by comparable erosion took place in Montana and Wyoming lends support to this conclusion.

[10] Anderson, A. L., Some Miocene and Pleistocene drainage changes in northern Idaho: Idaho Bur. Mines and Geology Pamph. 18, pp. 1-28, 1927.

[11] Bretz, J. H., The age of the Spokane glaciation: Am. Jour. Sci., 5th ser., vol. 8, pp. 334-342, 1924.

[12] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, p. 406, 1924.

[13] Pardee, J. T., Geology and mineral deposits of the Colville Indian Reservation, Wash.: U. S. Geol. Survey Bull. 677, pp. 47-53, 1918. Bretz, J. H., Glacial drainage on the Columbia Plateau: Geol. Soc. America Bull., vol. 34, pp. 573-608, 1923.

[14] Leverett, Frank, Glacial formations in the western United States: Geol. Soc. America Bull., vol. 28, p. 143, 1917.