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UNITED STATES DEPARTMENT OF THE INTERIOR

PHYSIOGRAPHY AND GLACIAL GEOLOGY OF EASTERN MONTANA AND ADJACENT AREAS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 174

UNITED STATES DEPARTMENT OF THE INTERIOR
Ray Lyman Wilbur, Secretary

GEOLOGICAL SURVEY
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Professional Paper 174

PHYSIOGRAPHY AND GLACIAL GEOLOGY OF EASTERN MONTANA AND ADJACENT AREAS

BY

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

GROUND WATER BRANCH
22 E. MAIN ST. P. O. BOX 24
NEWARK, DELAWARE

For sale by the Superintendent of Documents, Washington, D. C. - Price $1.00 (Paper)

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SUMMARY

Introduction.—The northern Great Plains rise gradually westward from about 2,000 feet above sea level on the Coteau du Missouri in North Dakota to 5,000 or 6,000 feet at the Rocky Mountain front. Though largely smooth, the plains are considerably dissected, having a relief of 500 to 1,500 feet. There are also several outlying mountain groups whose crests range in altitude from 6,300 to 9,000 feet. The Crazy Mountains attain 11,000 feet and the Big Horn Mountains, in northern Wyoming, 13,000 feet. The plains rocks range in age from early Cretaceous through Eocene, with a few remnants of Oligocene.

Cypress Plain.—The Cypress Hills of southern Alberta and Saskatchewan are capped with coarse Oligocene river gravel and fossiliferous sands, now 2,000 feet above the South Saskatchewan River. These deposits and similar high-level gravel-capped erosion remnants tentatively correlated with them indicate that by Oligocene time the Rocky Mountains of Montana and Wyoming and the northern Great Plains were sufficiently high to afford strong stream gradients for hundreds of miles to the east and northeast. These flat-topped remnants represent the Cypress Plain, which headed at levels now high on the Rocky Mountains. They appear to correspond with such old erosion surfaces as the subsummit peneplain on the Beartooth and Big Horn Mountains, which is probably not younger than Miocene.

The development of the Cypress Plain was followed by differential uplift and dissection to depths ranging from 700 to 1,500 feet on the plains and possibly 2,000 to 3,000 feet in the mountains.

Flaxville Plain or No. 1 bench.—There are throughout the region remnants of a series of well-marked gravel-covered alluvial terraces and benches which may be grouped into three sets, successively lower and younger than the Cypress Plain. These were originally miles in width, smooth, and flat, and they bevel the upturned edges of limestones, shales, and sandstones, ranging in age from Mississippian to Eocene, showing that they are the product of stream erosion and deposition during successive long periods of freedom from uplift or deformation. They are separated by vertical intervals ranging from 100 to 600 or 800 feet, so distributed in general as to indicate that the periods of planation alternated with periods of regional differential uplift which rejuvenated all the streams and caused them to cut to successively lower levels.

The first set below the Cypress Plain is correlated with and includes the Flaxville Plain of northeastern Montana, described by Collier and Thom. With the Flaxville are correlated the remnants of the highest of the alluvial gravel fans and terraces now preserved near the mountains. These originally coalesced in a very extensive piedmont terrace, 1,000 to 1,500 feet below the position of the Cypress Plain at the mountain fronts. The presence of Pliocene fossils with those of Miocene age in sandy parts of the Flaxville gravel indicates that streams were flowing on the Flaxville Plain late in Tertiary time.

Pleistocene epoch.—Onto the Piedmont part of the Flaxville Plain the first known Rocky Mountain glaciers of this region extended before the plain was greatly dissected. The till on the high bench remnants at the east side of Glacier National Park has been considerably modified by weathering and is in part cemented to a hard tillite. Possible remnants of this early Pleistocene till farther south are also badly weathered.

It is not certain that the Keewatin ice sheet crossed the Coteau du Missouri and invaded Montana as early as the Kansan stage of glaciation.

Early and middle Pleistocene terraces.—The second set of terraces comprises surfaces at two levels, which can not everywhere be differentiated. The lower of these is generally the most extensively preserved of all the terraces of this region. This appears to be the correlative of the Circle terrace of the Wind River Basin in Wyoming. The upper Missouri and Yellowstone Rivers probably flowed to Hudson Bay until the formation of the second set of terraces. Their combined waters were probably finally diverted southward through the Dakotas by the Kansan advance of the Keewatin ice sheet.

The presence of a third set of terraces indicates another stage of downcutting by the streams, followed by lateral planation and deposition of river gravel. Away from the mountains the third terrace is generally 100 to 200 feet or more below the lower second terrace and is confined between the main lines of bluffs bordering the inner valleys, which are from 1 mile to several miles wide.

Before the invasion of Montana by the Keewatin ice sheet at the Illinoian or the Iowan stage of glaciation the Missouri River, which was then flowing in the valley now occupied by the Milk River east of Havre, had cut down well below the level of the present bottom of that valley. This cutting may perhaps have been due to rapid deepening of the Missouri gorge through the Dakotas after the final diversion of the river southeastward. The refilling resulted from subsequent obstruction of the drainage by advance of the Keewatin ice sheet at the Illinoian or the Iowan stage.

Interglacial stream gravel found in places underlying Wisconsin and pre-Wisconsin (Illinoian or Iowan) drift, both south and north of the international boundary, includes some, at least, of what Dawson and McConnell designated "Saskatchewan gravel."

Illinoian or Iowan (?) stage of glaciation.—After the erosion of the Missouri gorge in North Dakota the Keewatin ice sheet advanced to and across this gorge, and in Montana it diverted the Missouri River from the north side to the south side of the Bearpaw and Little Rocky Mountains. It extended nearly to the site of Great Falls and diverted the Missouri River, also in that vicinity. It seems probable that this incursion of the Keewatin glacier was as late as either the Illinoian or the Iowan stage of glaciation, to judge from the very large amount of erosion that had occurred previously during Pleistocene time and from the relatively small amount of erosion and modification of the pre-Wisconsin Keewatin drift since its deposition. There is evidence of a pre-Wisconsin advance of the Rocky Mountain glaciers down to low levels, but the evidence noted in this part of Montana is not so conclusive as at some other places.

Wisconsin stage of glaciation.—At the early or middle Wisconsin stage of glaciation the Keewatin ice sheet covered most of the area north of the present channel of the Missouri River and extended southwestward nearly to Great Falls, Mont. It reached some points that are now 3,500 to 4,450 feet above sea level. East of the Little Rocky Mountains the limit of the Keewatin drift is not very well marked. At a later Wisconsin advance the Keewatin glacier extended but 10 to 40 miles into the northeastern townships of Montana.

Topographic relations show that after the deposition of the high-level pre-Wisconsin drift of the Rocky Mountain glaciers on the piedmont portion of the Flaxville Plain, in early Pleistocene time, and before these glaciers readvanced at the Wisconsin stage, canyon cutting to depths of 1,000 feet or more occurred, and valleys were eroded across the plains to depths ranging from 1,000 feet near the mountains to 500 feet or more in eastern Montana.

The relations of the low-level moraines of the mountain glaciers to the adjacent moraine of the Keewatin ice sheet are such that there is no doubt as to their approximate contemporaneity in Wisconsin time. The moraines of the mountain glaciers are mapped and described, but they have not been clearly differentiated as of early, middle, and late Wisconsin age.

Recent.—Certain phenomena suggest that the regional uplifts continued through Pleistocene into Recent time. The depths of Recent stream erosion range from 50 to 200 feet, and in general the streams appear to be still actively cutting downward. The glaciers now existing in the mountains are not described in this paper.

PHYSIOGRAPHY AND GLACIAL GEOLOGY OF EASTERN MONTANA AND ADJACENT AREAS

By William C. Alden

INTRODUCTION

FIELD STUDIES

In the summers of 1911 and 1913 the writer was engaged in the study of the glacial phenomena of Glacier National Park in connection with a geologic survey being made by a party under the direction of M. R. Campbell. A part of the summer of 1912 was also spent in adjacent parts of the Blackfeet Indian Reservation, Mont., and in southern Alberta in a reconnaissance on the plains adjacent to the east front of the mountains, in company with Eugene Stebinger. In the course of these studies it was found that some of the high mesas and benches near the mountain front, the gravel caps of which had been regarded as preglacial alluvial fans, also carried very old glacial till. The topographic relations of these till remnants, taken in connection with their partial cementation to hard tillite and their modification by leaching and weathering, seemed to indicate that the till was the product of early Pleistocene mountain glaciation, which occurred long before the extension of the mountain glaciers of the Wisconsin stage down the valleys that now intervene between the several high mesas or benches capped with the ancient till. The relations seemed to indicate that the mountain gorges and their valley extensions on the adjacent plains had been deepened 1,000 feet or more between the earlier and the later mountain glaciations.

In 1915 Stebinger, with the assistance of E. S. Corbett, who had been the writer's assistant in Glacier National Park in 1913, and others, continued the geologic mapping of the park. In 1911 and later seasons Stebinger carried on studies of the relations of the glacial deposits and the high-level bench gravel in connection with areal mapping of the older rocks on the part of the plains adjacent to the mountains between the international boundary on the north and the vicinity of the Sun River on the south. These studies tended to corroborate the inferences drawn in 1911 concerning the relations of the high-level and the low-level drift of the mountain glaciers, although no high-level glacial deposits were then identified near the mountain front south of Marias River, where the high benches have mostly been cut away.

Study of the drift of the Keewatin ice sheet on the plains east of the mountains showed that F. H. H. Calhoun was probably right in concluding that the uppermost continental drift is of Wisconsin age. It was evident that its deposition took place long after that of the high-level bench gravel, for thicknesses of hundreds of feet of shale and sandstone were removed from the plains of northeastern Montana, leaving only dissevered remnants of these high gravel-covered terraces and benches before the Keewatin glacier of the Wisconsin stage invaded Montana. A somewhat older sheet of Keewatin drift extends outside the limit of the Wisconsin glaciation to and across the Missouri River in Montana and northwestern North Dakota, and study shows that it also was deposited subsequent to the cutting down of the plains and even after the Missouri River had completed the deepening of its preglacial valley in Montana and had been diverted to its present course and eroded its gorge in North Dakota and after the Yellowstone Valley had reached its present depth.

Studies which gave the writer a wider personal acquaintance with the several drift sheets were carried on in the summers of 1914 and 1915, when he collaborated with M. M. Leighton, of the Iowa Geological Survey, in a critical field study of the Iowan drift and associated deposits of eastern Iowa, with examination of the older drifts at numerous places in Illinois, Iowa, and Nebraska for comparison. Some further studies of the Kansan and Nebraskan drifts were also made in western Iowa and eastern Nebraska in 1919. All these studies might, in a sense, be regarded as preparatory to the regional study of which the present paper treats.

Reports of the men engaged in geologic mapping on the plains of Montana and Wyoming showed that there are numerous remnants of gravel-capped terraces and high-level benches widely scattered in the upper Missouri [1] and Yellowstone drainage basins, but

[1] The term "upper Missouri River" as used, for convenience, in this paper refers in the main to some, if not all, of that part of the river between Yankton, S. Dak., and the point where the stream leaves the mountains, about 40 miles above Great Falls, Mont. It does not include the part of the river above the mountain front, which is, perhaps, more properly the real upper Missouri or should, at least, be included under that term. In a few places, as is evident, the term as used in this paper excludes the part of the course below Williston, N. Dak.

no one was making or had made any serious attempt at regional study, correlation, and interpretation of those features and of their relations to the glacial deposits. It therefore appeared important to make a critical study of the character and age of the several drift sheets and of their relations to these several sets of gravel-covered terraces and benches, and a plan was made accordingly.

The plan was to make a rapid and widely extended regional reconnaissance with the view of supplementing and correlating the results of the earlier studies of the drift by Calhoun and the more or less incidental observations of the many other geologists above noted. In the summer of 1916 work was begun at the great Altamont moraine of the Wisconsin drift sheet, on the Coteau du Missouri, in the northwestern counties of North Dakota, and it proceeded westward with traverses by automobile crisscrossing the country north of the Missouri River at intervals of about 8 or 10 miles and including a belt 10 to 50 miles wide north of the international boundary. It was thought that the Altamont moraine might be found to swing westward about the Wood Mountain upland in southern Saskatchewan, then to reenter Montana and extend southwestward to the Little Rocky Mountains, to connect with the line traced by Calhoun as the outer limit of the Wisconsin drift. As noted below (p. 129), however, the moraine was not found to have such a trend. Apparently it continues northward and northwestward in Saskatchewan beyond the region traversed.

A. J. Collier and W. T. Thom, jr., following C. E. Bauer, in 1915 had studied the Flaxville gravel of northeastern Montana, and the fossils collected by them gave some basis of approximate age determination for one of the main sets of terraces and benches. From this determination, taken in connection with the results of the earlier studies of the fossiliferous gravel on the Cypress Hills of southern Saskatchewan by McConnell, Cope, Weston, and Lambe, it appeared that there might be in this region data for working out the physiographic history of the northern Great Plains. From these beginnings it was hoped to proceed continuously, but not until 1920 was there opportunity to go ahead with the study. In the summer of that year and in 1921 to 1924 the study was extended until it covered the larger part of the plains of Montana, parts of northwestern North Dakota, the Big Horn Basin, Wyo., and the environs of the Big Horn and Wind River Mountains, and subsequently it was extended much farther south. Except the studies in the mountains of Glacier National Park and a few trips in and near Yellowstone National Park and in the Big Horn Mountains, the investigations here described have been confined almost wholly to the plains. In most places the field examinations were extended up to the mountain fronts or up the valleys to the moraines of the mountain glaciers of the last great ice extension at the Wisconsin stage. In 1921 and 1923 a preliminary attempt was made to check across to the intramontane valleys in the region of Bozeman, Townsend, and Helena, Mont., and to correlate the writer's results with those of similar studies being initiated by J. T. Pardee on the upper Missouri and on tributaries of Clark Fork of the Columbia River. Pardee's studies, and also those of the present writer, were subsequently extended westward into northern Idaho and eastern Washington.

When it is realized that the vast area in which the writer's traverses were made east of the Rocky Mountain front, including the Big Horn Basin, is equal in size to the whole of New York, Pennsylvania, New Jersey, Delaware, and Maryland—nearly 112,000 square miles—the necessarily general nature of the reconnaissance and more or less tentative character of the correlations and interpretations will be evident. During much of this time, however, detailed areal mapping was being done by others, principally by men engaged in mapping the coal, oil, and gas lands of Montana and Wyoming, and many of these men actively cooperated with the writer by locating and examining terrace gravel and glacial deposits wherever they were found and by noting their absence from other parts of the region. The names of the following may be noted in this connection, and citations of their publications and of many others will be found in the text: C. Max Bauer, A. L. Beekly, C. F. Bowen, W. R. Calvert, S. H. Cathcart, A. J. Collier, C. E. Dobbin, C. A. Fisher, M. I. Goldman, E. T. Hancock, C. J. Hares, F. A. Herald, D. F. Hewett, C. T. Lupton, L. J. Pepperberg, Frank Reeves, R. W. Richards, G. S. Rogers, Carl D. Smith, Eugene Stebinger, R. W. Stone, W. T. Thom, jr., and L. H. Woolsey.

The writer is under obligation to all the men cited above. Others have examined preliminary statements or outlines and have given suggestions. Among these may be gratefully noted T. C. Chamberlin, Frank Leverett, M. R. Campbell, Eugene Stebinger, A. G. Leonard, H. E. Simpson, and N. M. Fenneman. An excellent paper by Calhoun [2] has been very useful, and considerable excerpts from it have been incorporated in the present paper.

A preliminary presentation of the results of this study constituted the address of the writer as retiring president of the Geological Society of Washington, December 13, 1922. A second presentation was made to the Geological Society of America at the Washington

[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.

meeting December 27, 1923, and the first publication of these summaries was in the Bulletin of the Geological Society of America, volume 35, pages 385–424, 1924.

GENERAL CHARACTERISTICS OF THE NORTHERN GREAT PLAINS

The northern Great Plains rise gradually westward from altitudes between 1,800 and 2,400 feet above sea level on the Coteau du Missouri east of the Missouri River, in North Dakota, to 5,000 or 6,000 feet at the foot of the Rocky Mountains. The Rocky Mountain front in general rises abruptly from the prairies, and a short distance back from the front are peaks rising to altitudes of 9,000 to 10,000 feet in Glacier National Park and 11,000 to 13,000 feet and more in the Big Horn Mountains and the rugged region north and east of Yellowstone National Park. In this connection attention may be called to the fact, which is probably already familiar to many, that the country east of the mountains, though known as the northern Great Plains, is far from being a smooth, flat surface. It is true that there are some flat tracts and large gently rolling areas and that to an observer on a high point in the mountains the whole vast plain looks as flat as a floor in contrast with the boldness of the mountain ridges. This impression is, however, due to the fact that the features are much smaller and lower than the mountains and that the details are lost in the hazy distances. Particularly outside the drift-coverd part of the plains—that is, in most of the plains region south and west of the Missouri River—there are large areas of very rough country. Typical badlands occur in the breaks along the Missouri and Yellowstone Rivers, where there is deep and thorough dissection, and in the larger interstream tracts ridges rise in places 500 to 1,500 feet above the valley bottoms, with many bold cliffs and picturesque towers and pinnacles, especially where the eminences are capped with sandstone.

The Missouri and Yellowstone Rivers flow for the most part in rather narrow young valleys bordered by lines of abrupt bluffs 100 to several hundred feet in height. In many places on the Missouri River below Great Falls, Marias River, the Teton, the lower Musselshell, and the Little Missouri the inner valleys are narrow gorges approached with difficulty except on the main graded roads.

MOUNTAIN OUTLIERS

There are several small outlying mountain groups which rise above the plains. With these may be grouped the Sweetgrass Hills, three igneous laccolithic buttes of early Tertiary age near the Canadian line, about 6,300 feet above sea level. The mountains comprise the Bearpaw Mountains, made up of post-Eocene volcanic rocks (6,000 to 7,000 feet above sea level); the Little Rocky Mountains (6,000 to 6,500 feet), laccoliths of early Tertiary age; the Highwood Mountains, volcanic rocks of Tertiary age (7,240 feet); the North Moccasin, South Moccasin, and Judith Mountains, early Tertiary laccoliths (6,000 to 8,600 feet); the Big Belt, Little Belt, and Big Snowy Mountains, early Tertiary anticlinal uplifts and faulted laccoliths (7,000 to 9,000 feet); and the Castle and Crazy Mountains, faulted laccoliths and intrusive rocks of Eocene age (8,000 to 11,000 feet). To the south are the Pryor Mountains (nearly 8,800 feet) and the Big Horn Mountains (over 13,000 feet), separated by the lower Big Horn Canyon, both early Tertiary anticlines or uplifts. Farther east are the Black Hills.

ROCKS OF THE PLAINS

The rocks of the plains in Montana and Wyoming are mostly shale and sandstone ranging in age from early Cretaceous through Eocene. The particular deposits described in this paper are mostly nonglacial river gravel, ranging in age from Oligocene through Pleistocene, and glacial drift.

In western North Dakota there are several isolated buttes capped with deposits of supposed Oligocene age. One of these, Sentinel Butte, about 10 miles east of the Montana line, rises 3,430 feet above sea level and is the second highest point in North Dakota. It is not certainly known that any Oligocene formations remain on the plains of Montana other than some remnants in the southeast corner which are shown on geologic maps as of White River age. The possibility that there may be other small remnants of Oligocene or Miocene deposits is discussed below. Not since the deposition of the Cannonball marine member of the Lance formation, near the end of Cretaceous or the beginning of Tertiary time, has this region stood so low that marine waters invaded western North Dakota or Montana.

BENCHES AND TERRACES

The term "bench" is generally used in this region but perhaps more loosely than in this paper. The writer is applying it only to those nearly flat features which are clearly remnants of ancient river plains and which are not due simply to the stripping of softer shale from harder flat-lying sandstone. Most of these benches bevel indiscriminately the upturned edges of shale and sandstone, and most of them are thickly covered with coarse gravel below thin loamy soils. The name "bench" is here applied more or less indiscriminately to the tops of gravel-capped plateaus or mesas which, like the Cypress Hills, stand well above their immediate surroundings, and also, in places, to typical terraces, which are bordered on the one hand by lower lands and on the other by slopes rising to higher lands. These features merge into one another. The plateaus and mesas are in many places, especially near the mountains, erosional remnants of great alluvial fans. Some of these may have extended far out over the northern Great Plains and may have coalesced into continuous smooth, flat tracts of vast extent, such as are preserved in the High Plains farther south. Others narrowed between somewhat higher lands on each side and extended down the valleys as broad, smooth, gravelly bottoms. These are now deeply dissected terraces.

OLIGOCENE EPOCH

THE CYPRESS PLAIN AND UNDERLYING ROCKS

With the end of Fort Union time in northern Montana and the adjacent parts of southern Alberta and Saskatchewan the great fresh-water lakes and marshes in which extensive deposits of sand, clay, and lignite had been accumulating appear to have been drained or desiccated to a large extent. This was probably an accompaniment, if not a direct result, of the elevation of the Rocky Mountains and bordering plains. Near the mountains in southern Alberta and northern Montana as far south as the Sun River west of Great Falls the latest of the plains rocks, which were involved in the folding and crumpling resulting from the orogenic movement, are beds of the Willow Creek (Paskapoo and Edmonton of McConnell) and St. Mary River formations.

Fronting the Bridger Range the beds of the Livingston formation, partly Eocene and partly Upper Cretaceous, are upturned. In the region south of the Yellowstone River, including the Clark Fork and Big Horn Basins in Wyoming, the beds of the Wasatch formation and of the Linley conglomerate north of Red Lodge (which may also be of Wasatch age) are upturned near the mountain front, though unconformable on Fort Union beds. So also the Kingsbury conglomerate member of the Wasatch formation bordering the east front of the Big Horn Mountains was involved in the mountain uplift and is tilted.

There is little evidence in hand to show the progress of this uplift during Eocene time. Undoubtedly streams had been flowing eastward from the rising land areas into the contracting bodies of fresh water on the plains ever since the last marine waters had disappeared. These streams swung to and fro across the plains and, cutting away the tops of the rising folds and faulted blocks in the disturbed belt bordering the mountains, beveled the edges of the early Tertiary and Cretaceous rock formations and may have maintained a fairly uniform surface.

The altitude of the land at the beginning of the epoch of folding and faulting is not known, but apparently by Oligocene time it stood sufficiently high to induce vigorous stream flow for a long distance eastward, as shown by the character of the materials then laid down. Moreover, it also appears that by Oligocene time erosion of the folded and faulted rocks of the front range of the Rocky Mountains in the Glacier National Park region had progressed far enough to remove much of whatever mantle of Cretaceous and early Tertiary sediments there was on the uplifted mass and to uncover the limestone, quartzite, and argillite of the pre-Cambrian formations brought up in the Lewis overthrust fault. This conclusion appears to be justified by the discovery of Oligocene fossils in the stream deposits that cap the Cypress Hills Plateau in southern Saskatchewan. The lithologic composition of the conglomerates of the Big Horn Basin suggests that a good deal of erosion of the mountain belts had already occurred in Fort Union and Wasatch time.

The Cypress Hills Plateau (pl. 1) lies mostly in southwestern Saskatchewan, in the districts of Maple Creek and Cypress, whence it extends westward about 20 miles into the district of Medicine Hat, southeastern Alberta. It is a high tract nearly 80 miles in length from east to west and tapering westward, with somewhat irregular outline, from a maximum width of about 20 miles in the eastern part to a point, the Head of the Mountain, at the west. It is really a plateau, as its top is smooth where not dissected by coulees, and it slopes gradually eastward from an altitude of about 4,850 feet at the west end to 3,700 feet or less in the eastern part. The top is partly grazing land but largely under cultivation. The marginal slopes are generally steep, locally abrupt, and in places precipitous. The north slope, in the western part at least, is embraced in the Dominion Forest Reserve and is covered with beautiful spruce and pine trees which present a pleasing contrast to the vast expanse of treeless plains below. It is the highest land in this part of the Great Plains and a prominent topographic feature.

The margins and top are somewhat dissected by coulees, and one "sag," the "Gap," about 6 miles in width, cuts entirely through, severing the western third from the broader part of the plateau to the east. This western part was examined briefly by the writer in August, 1920; for additional information on this and the other parts he is indebted to the work of previous writers, Dawson, McConnell, and Lambe.

The Cypress Hills Plateau forms part of the Continental Divide, and from its north slope the drainage goes principally to the South Saskatchewan River and partly to some of the small and more or less saline lakes that dot the plains. Most of the plateau drains southward and several of the streams are tributary to the Milk River. One of these, the Frenchman River, flows close to the south margin of the eastern part of the plateau in a gorge several hundred feet deep walled by precipitous cliffs of shale and sandstone. This gorge is now traversed by a branch of the Canadian Pacific Railway for about 15 miles west of the vicinity of the village of East End. East End Coulee, through which the railway runs northeastward across the divide, separates the Cypress Hills Plateau from a somewhat lower tract to the east known as the Mud River Plateau, from which a high belt extends more or less continuously eastward through the district of Notukeu to the Wood Mountain upland, in the Willow Bunch district.

The plateau is an erosion remnant in which the Cretaceous shale is overlain by shale and sandstone of the Lance and Fort Union formations, which have been entirely removed from the area to the north and south as far as the Missouri River and to the west for a distance of 100 miles. The western segment of the Cypress Hills Plateau is capped with a thick bed of coarse waterworn gravel, evidently a stream deposit. On the top of the ridge the gravel is fairly well covered by a thin loamy clay soil and is not generally reached by the plow. At the crests of slopes and wherever this soil cover is washed away, however, smoothly rounded cobblestones strew the surface, and in places where seepage of water occurs there have been landslides on the slippery underlying clay. In some places the scarps developed in this manner expose the gravel in section. One of the best of these exposures seen by the writer is at the north edge of the plateau about a mile from the west end. This scarp is a cliff about 30 feet high above a talus of loose pebbles and large blocks of conglomerate. (See pl. 3 *A*.) The material exposed is gravel composed of smoothly rounded pebbles and cobbles of quartzite and fine-grained siliceous argillite, with some chert and vein quartz, ranging in size from a fraction of an inch to 8 by 10 by 12 inches. A large percentage of the pebbles are over 6 inches in diameter. The interstices between the cobbles are filled with small pebbles and some sand, and the whole is cemented by calcium carbonate to a conglomerate.

McConnell [3] states that

west of the "Gap" this formation consists of a uniform sheet of hard conglomerate about 50 feet thick, which is well exposed in many places in the valleys of Battle Creek, Fourmile Coulee, and along the edges of the plateau. In the eastern part of the hills the conglomerate is usually associated with beds of sandstone, sands, clays, and marls, and the thickness of the whole deposit increases to about 500 feet.

The conglomerate which forms such a marked feature of the Miocene [Oligocene] deposits of the Cypress Hills is usually composed of quartzite pebbles cemented together by carbonate of lime but also appears under a number of other forms. In some places the pebbles lie loosely in a matrix of coarse yellowish sand, and in others they are consolidated by a ferruginous cement. Beds several feet thick also occasionally occur which contain nothing but loose pebbles. The conglomerate sometimes contains interstratified beds of coarse sands, into which the pebbles seem to grade, and also beds of white or cream-colored clays and sands, which occasionally hold calcareous nodules, some of which when broken across were found to be spotted by small black concretionary grains of oxide of manganese. The pebbles of the conglomerate are nearly always composed of hard quartzite and vary in size from coarse sand to 8 and 9 inches in diameter, though the usual size is from 2 to 4 inches. They are usually white on a fresh fracture, but gray and flesh-colored tints are also common. They are sometimes found forming the lower surface of hard sandstone beds or scattered more or less sparingly through them. Beds of pebble conglomerate, though more frequent and larger near the base of the Miocene [Oligocene], are found at irregular intervals all through it and are of all thicknesses, from a single layer of pebbles up to beds fully 50 feet thick. In many cases the formation consists of a single thick bed of this rock. Besides the pebble conglomerate, beds composed of angular pieces of clays inclosed in a matrix of hard sandstone and forming a species of breccia are occasionally found.

The sands of the Miocene [Oligocene] sometimes form hard beds, from 1 to 2 feet thick, but are usually only slightly indurated and are nearly always affected by false bedding. In one place, near the eastern escarpment, a bed was observed which consists of hard, clean, angular siliceous grains, nearly all of uniform size and apparently quite loose and unstratified. This bed contained a few pebbles and rolled fragments of fossilized wood and bones.

Small beds of impure carbonate of lime, or marl, are also occasionally found amongst the deposits of this formation.

The best exposures in the eastern part of the plateau are north of the village of East End, in Bone Coulee, in which head the North Fork of Swift Current Creek and Farewell [Frenchman] Creek. McConnell [4] states:

The rocks exhibited in these sections consist of pebble and clay conglomerates, with occasional beds of loose pebbles, hard and soft sandstones, the latter usually very coarse grained and affected with false bedding, clays of various colors but usually dark gray, and small beds of impure limestones and whitish marls. The total thickness of the whole deposit at this place is about 500 feet, but going west it thins out rapidly, and in a few miles everything but the pebble conglomerate disappears.

McConnell in 1883, T. C. Weston in 1884, 1888, and 1889, and L. M. Lambe in 1904 collected vertebrate and a few invertebrate fossils, mostly from Bone Coulee, and the study of these resulted in the conclusion that the deposits capping the Cypress Hills are of Oligocene age. Lambe [5] states:

Cope, in his memoir of 1891, qualifies McConnell's assignment of the uppermost beds of the Cypress Hills to the Miocene by describing them as of Oligocene or lower Miocene age. Matthew would accord them a more definite horizon at the bottom of the Oligocene and has expressed the opinion that they are probably of approximately the same age as the *Titanotherium* beds at Pipestone Springs, Montana. This opin-

[3] McConnell, R. G., Report on the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., vol. 1, pp. 30c–31c, 1885.

[4] Idem, p. 32c.

[5] Lambe, L. M., The Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan: Canada Geol. Survey Contr. Paleontology, vol. 3, pt. 4, p. 7, 1908.

ion appears to be borne out to some extent by the list of species from Pipestone Springs, published by Dr. Matthew in 1903, and the collections from the Cypress Hills, supplemented by the material secured in 1904.

The vertebrate fossils are remains of 50 species of fishes, reptiles, and mammals, among which are lizards, snakes, crocodiles, marsupials, rodents, members of the cat and dog families, horses, hyracodonts, rhinoceroses, and titanotheres. Lambe says:

> Some of the groups have since become extinct; others have undergone great changes and are with difficulty recognized in their descendants of the present day; whilst a few are represented by existing species that show but slight difference in form and structure.

It seems to the present writer beyond question that the materials capping the Cypress Hills are principally, at least, alluvial deposits formed by a vigorous stream heading in the Rocky Mountains. This is well stated by Lambe as follows:

> That the Cypress Hills Oligocene deposits were the result of rapidly flowing water from the west is evident. The thick basal beds of rounded pebbles represent the work of a strong transporting force, such as would be supplied by a turbulent stream of considerable size carrying eastward material from the Rocky Mountains. The sands show false bedding as a result of varying currents. With the accumulation of material eastward, and a consequent reduction of the transporting force, beds of finer material were deposited at a higher level and probably on extensive areas of overflow.

The pebbles examined by the present writer are mostly well rounded and have remarkably smooth and evenly polished surfaces, many of which are covered with percussion marks such as are produced by stones striking sharply against one another in a strong current. The source of the material is clearly the Rocky Mountains, 150 to 200 miles west of the head of the plateau. In view of this distance, the size of the larger stones is remarkable. Of those shown in Plate 3 *B* the largest have dimensions of 8 by 10 by 12 inches. None of the stones examined show any evidence of transportation by glacier ice.

McConnell[6] has pointed out that

> The area now covered by the Cypress Hills has been changed from a depression in Miocene [Oligocene] times into the highest plateau on the plains, which is its present position, entirely by the arrest of denudation over its surface by the hard conglomerate beds which cover it, whilst the surrounding country, destitute of such protection, has been gradually lowered and so affords an index of the amount of material removed from the neighboring plains in the age intervening between the deposition of the Miocene [Oligocene] and the glacial period. The conglomerate capping now overlooks, from a height of fully 2,000 feet, the lowest part of the plains stretching from the western base of the plateau to the mountains.

The bed of the ancient river must have risen rapidly upstream in order, as McConnell states, "to induce a current powerful enough to urge forward such immense quantities of pebbles and boulders 200 miles from their nearest source. For this work an easterly slope of at least 15 feet per mile would be required." This is about the present gradient of the base of the alluvial deposit that caps the plateau. The slope of the remarkably flat surface of the deposit on the western segment of the plateau is now about 12 or 13 feet to the mile.

For convenience of reference the plain now represented by the top of the Cypress Hills Plateau is here designated the Cypress Plain. This name may be taken to include all other remnants of similar valley plains, alluvial fans, terraces, and benches within the basins of the Big Horn, the Yellowstone, the upper Missouri east of the mountains, and the South Saskatchewan and their tributaries that can be identified as representing approximately the same stage of physiographic development.[6a]

In order to get some conception of the probable relations of the plains and mountains in Oligocene to Miocene time, a gradient similar to that found on existing remnants of the next lower terraces of the region may be projected from the head of the Cypress Hills to the mountains of the Glacier National Park.[7]

The distance from Chief Mountain to the Cypress Hills is about 155 miles. The slope away from the mountain may be postulated as 5 miles at 100 feet to the mile, 10 miles at 75 feet, 20 miles at 40 feet, and 100 miles at 10 feet—a total fall of 3,450 feet in 155 miles—and it may have been even steeper. Such a gradient rising in a westerly direction from the head of the Cypress Hills at about 4,850 feet above sea level would reach the mountains at about 8,300 feet—that is, about 750 feet below the crest of Chief Mountain—and, if continued westward at 100 feet to the mile, would overtop all but the highest peaks east of and along the Continental Divide in Glacier National Park. Mount Cleveland and Mount Siyeh would rise about 1,000 feet above it. It would be nearly 3,000 feet higher than the St. Mary River (which is 4,200 feet above sea level at the international boundary) and about 2,000 feet higher than the gravel-capped ridges bordering the mountain front as far south as Two Medicine Lake. Study of the later terraces described elsewhere in this paper leads to the

[6] McConnell, R. G., op. cit., pp. 69c, 70c.

[6a] M. Y. Williams (The physiography of the southwestern plains of Canada: Royal Soc. Canada Trans., vol. 23, sec. 4, p. 65, 1929) thinks it probable that the Cypress Plain on top of the Oligocene deposits "is early Miocene in age rather than 'Oligocene-Miocene.'"

[7] In the projection of stream gradients and the attempted correlations on the basis of stream gradients, relative height above the present streams, and other physiographic relations in this study, there is no pretense of accuracy of detail; approximation is the best that can be hoped for, and there is necessarily considerable room for differences of opinion as to some conclusions. Barometric readings have generally been taken where published data on altitudes were not available, and projected gradients have been assumed corresponding with those which are now found on benches and terraces in similar situations in this region, with some allowance for local modifying factors.

conclusion that the projected gradient is not too steep, especially if the effect of subsequent eastward tilting of the plains is included. At a gradient not quite so steep the slope would coincide with the smoothly worn tops of some of the mountains, such as Flattop Mountain, north of St. Mary Lake. (See pl. 2 *A*.) So far as known to the writer, there is no evidence that the mountains have risen less than the bordering plains since Oligocene time. Probably they have risen more than the plains.

The genetic relations of such a gravel-covered erosional surface to the development of the Lewis overthrust fault are not considered in this paper. It may be noted in passing, however, that the lithologic composition of the Oligocene gravel on the Cypress Hills suggests that the Lewis overthrust faulting and the associated folding occurred long enough before the end of the Oligocene epoch for the pre-Cambrian rocks to be denuded of their covering of Mesozoic and Paleozoic rocks and so exposed as to yield the quartzite gravel. It thus appears that the Lewis overthrust is much older than Willis's "Blackfoot peneplain,"[8] if by that is meant the plain of the highest benches now preserved near the mountains. As shown below, the latter plain is probably the correlative of Collier's "Flaxville Plain." Because of these facts the name "Blackfoot peneplain" is not used in this paper.

It is notable that nowhere back in the mountains of the Glacier National Park region are there, so far as known, any land forms of Oligocene time now preserved, unless they are the peaks of the mountains themselves, and even these have probably been greatly modified by erosion in subsequent ages.

McConnell evidently regarded the Oligocene fluviatile deposits on the Cypress Hills as originally distributed along a valley bordered by higher land. This may really have been the case, inasmuch as remnants of deposits of similar age, character, and topographic position are not now found for long distances either to the north or to the south.

Darton describes similar deposits of Oligocene and Miocene age that underlie a gently sloping, nearly flat plain which was originally continuous eastward from the front range of the Rocky Mountains south of the Wyoming-Montana line and which still extends over a large part of southeastern Wyoming, southwestern South Dakota, northeastern Colorado, and the western half of Nebraska. Concerning the conditions of deposition, Darton[9] writes as follows:

Later in Tertiary time, after the outlines of the great mountain ranges to the north and west had been carved, there was a long period in which streams of moderate declivity flowed across the central Great Plains region. These, with frequently varying channels and extensive local lakes due to damming and the sluggish flow of the waters, laid down the widespread mantle of the Oligocene or White River deposits. These began with the sands of the Chadron formation, which show clearly the course of old currents by channels filled with coarse sandstone and areas of slack water and overflow in which fuller's earth and other clays were laid down. The area of deposition of this series extended across east Colorado and Wyoming and west Nebraska and South Dakota and probably also farther north, for the deposits have been found in west Canada. Doubtless the original extent was much wider than the area in which we now find the formation, for much has been removed by erosion. The White River epoch was continued by the deposition of the Brule clay under conditions in which the currents were less strong and local lakes and slack-water overflows were more extensive. The Brule clay has about the same area as the Chadron and originally was much more extensive than it is at present.

At the beginning of Miocene time the general conditions had not changed materially, but doubtless for a while an extensive land surface existed in the central Great Plains area. In the stream channels extending across this surface the Gering formation was laid down, one channel extending across west Nebraska for some miles just south of North Platte River. Next came the deposition of a widespread sheet of sand derived from the mountains to the west, probably spread over the entire central Great Plains region by streams, aided to a minor extent by winds. The streams of this time shifted their courses across the plains, spreading the débris from the mountains in a sheet which in some parts of the area attained a thickness of 1,000 feet—a flat alluvial fan of wonderful extent. This is the Arikaree formation, which buried some of the lower ranges of the uplifts, as shown by the high altitudes to which it extends on the slopes of Rawhide Butte and along the front of the Laramie Range. It has been so widely eroded since its deposition that we do not know its original extent, but doubtless it covered most of the central Great Plains far to the east.

The character and topographic relations of the remnants of Oligocene deposits described above, the analogous relations of the Oligocene (White River formation) in South Dakota, southeastern Wyoming, northeastern Colorado, and Nebraska, and the conditions which developed later and which are described on pages 12–13 appear to afford justification for drawing a picture of northern Montana and the adjacent parts of Canada in Oligocene time as follows:

At the west the Rocky Mountains in Montana had by Oligocene or Miocene time risen to considerable height. The altitude above sea level is not known, but it seems probable that the crest of the range in the Glacier National Park region may have been within 3,000 feet of the present height, possibly 6,000 to 7,000 feet above the sea. Farther south the mountains may have been higher. Vigorous erosion in Glacier National Park had stripped off whatever covering of Mesozoic and Paleozoic rocks overlay the Algonkian limestone, quartzite, and argillite, and much erosion had been accomplished farther south concordantly with the rise of the mountains. The Great Plains had risen somewhat at the east and more at the west, so

[8] Willis, Bailey, Stratigraphy and structure of the Lewis and Livingston Ranges, Mont.: Geol. Soc. America Bull., vol. 13, pp. 310, 336–343, 1902.

[9] Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 185–186, 1905.

that such fresh-water lakes as there were in Eocene time were probably drained; the gradients of streams were increased, and vast quantities of coarse gravel and cobblestones and some clay and sand derived largely from the Algonkian rocks were swept eastward across the plains.

The eastern part of the Cypress Hills Plateau remnant of this ancient gravelly plain is about 850 miles from the nearest point of marine waters in Hudson Bay. If it is supposed that the altitude of the Cypress Hills has increased 2,000 feet since Oligocene time, the altitude of the head of the plateau at that time must have been about 2,800 feet and that of the east end 1,700 feet. This would mean an average gradient in this distance of about 2 feet to the mile, or about the same gradient as that of the present South Saskatchewan River, for that stream in the part of its course north of the Cypress Hills descends from an altitude of 2,142 feet at Medicine Hat to about 1,758 feet north of the east end of the Cypress Hills, and its waters reach sea level, by way of Lake Winnipeg and the Nelson River, at York Factory, the nearest point on Hudson Bay. This gradient is much lower than that postulated for the Oligocene stream from a point near the mountains eastward to and along the tract now representing the top of the Cypress Hills Plateau, and there is some doubt whether a stream flowing on such a gradient could have transported the coarse gravel now found scattered on lower areas far to the east. The presence of postglacial marine clay in the lower parts of the valleys tributary to the west coast of Hudson Bay up to altitudes of 500 to 600 feet may indicate that the average gradient on the lower South Saskatchewan and Nelson Rivers has been reduced about 1 foot per mile since Pleistocene time.

Dawson [10] in his journey westward on the Forty-ninth Parallel Survey found the first undoubted specimens of what he called "quartzite drift"—that is, quartzite pebbles from the Rocky Mountains like those of the Cypress Hills—about 145 miles east of the northeast corner of Montana.

At the stream gradient assumed west of the top of the Cypress Hills (p. 6), the streams would be issuing from the mountains of the Glacier National Park onto the plains on a surface somewhat above that now represented by the top of Flattop Mountain—that is, at an altitude now about 8,300 feet, then perhaps 5,300 feet, or not greatly different from that of the present streams at the mountain front. The mountains probably had a worn-down aspect by the end of Miocene time, but some peaks probably still rose 2,000 or 3,000 feet above the bordering plain. The valleys had not then been cut through the hard Algonkian rock into the soft Cretaceous shale below the plane of the Lewis overthrust—a condition developed subsequently which resulted in much slumping and consequent bold scarps. Neither had the stream-cut valleys then had their side and head slopes over-steepened by the plucking and scouring action of glacial ice. Some of the writer's conclusions have been discussed with reference to isostasy by Lawson.[11]

There is no evidence of an Oligocene or Miocene peneplain in the mountains of the Glacier National Park. South of Marias Pass the mountains are less well known to the writer, but topographic maps give little indication of a peneplain.

Some of the smooth parks on the Little Belt and Big Snowy Mountains suggest the presence of a peneplain, but they may be due, in part at least, to the nearly flat-lying positions of underlying rocks. In many places the condition was doubtless much the same as shown in Plate 2 *B*, a view taken on the summit of the southern part of the Big Horn Mountains 8,000 to 9,000 feet above sea level. Here the summit plain is underlain by gravel of supposed Oligocene or Miocene age, and in the background are mountain peaks rising 3,000 to 4,000 feet higher.

Weed [12] states that at the end of the Eocene epoch [including what is now termed Oligocene time] the entire Little Belt Mountains quadrangle was reduced to a gently hilly country bordered by a broad level plain. In a paper on the glaciation of the Crazy Mountains Mansfield [13] writes:

> Reference has been made to the gentle outlines of the upper topography of the northern section of the mountains. Loco Mountain, the main massif of that region, has a nearly flat top 3 or 4 miles long and 1 or 2 miles wide at an altitude of 9,000 feet. A small knoll rising 200 feet above the general level forms Loco Peak, the highest summit. The gentle outlines here mentioned have been produced upon both sedimentary and igneous rocks, regardless of structure, and represent an ancient surface of erosion.
>
> In the southern section the altitudes are greater and the general topography more rugged, but many of the ridges rise to fairly accordant levels, and here and there small remnants of a flat surface occur at an altitude of about 10,000 feet.

Mansfield apparently connects this summit erosion with the development of the surrounding high terraces (described on p. 25), of which remnants still persist. To the present writer, however, these terraces appear to be of later origin, and it seems possible that the smoothing of the top around Loco Peak may date back to the time of the Cypress Plain (Oligocene or Miocene).

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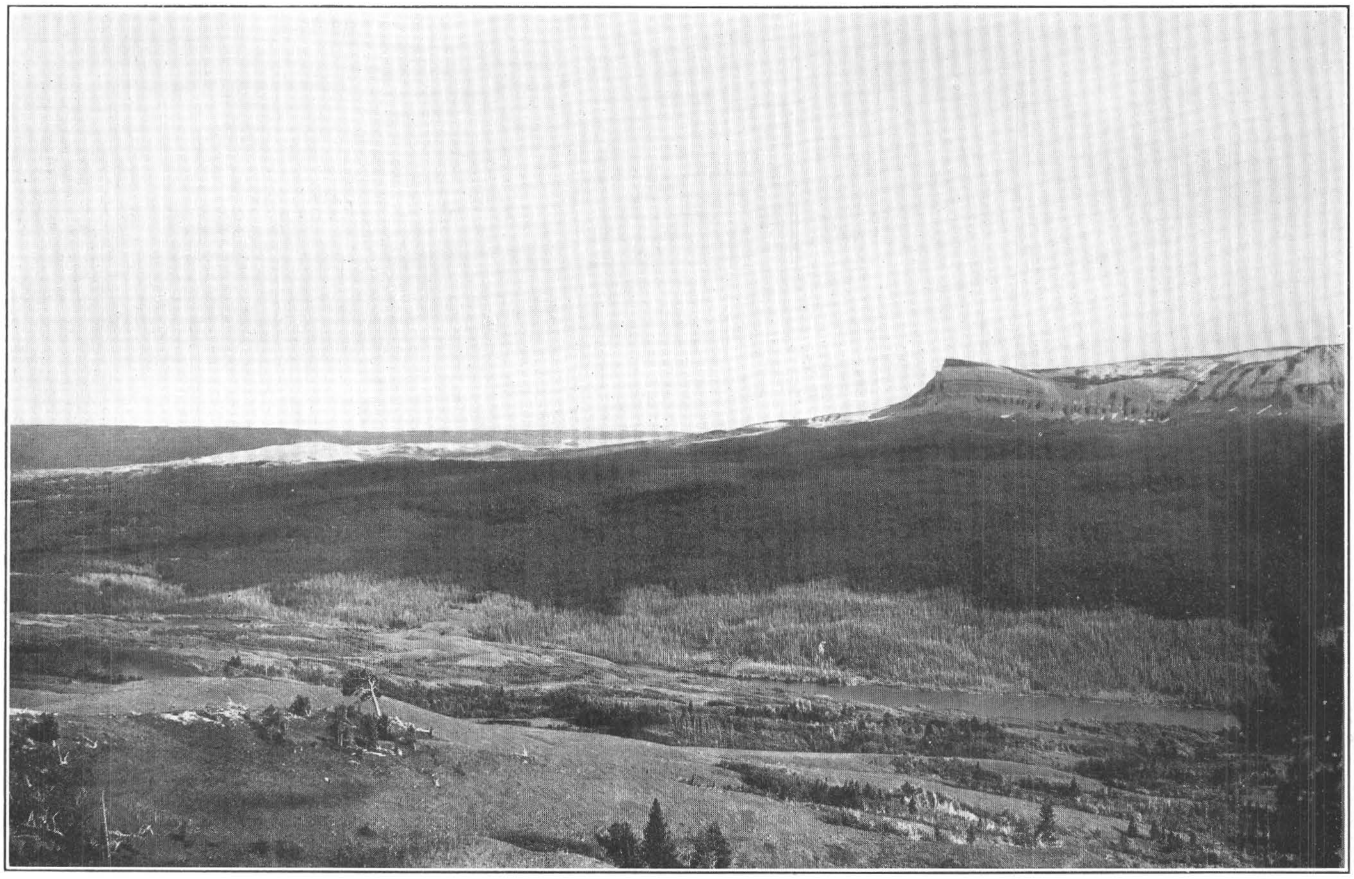
[10] Dawson, G. M., Report on the geology * * * of the 49th parallel, p. 225, 1875.

[11] Lawson, A. C., The Cypress Plain: California Univ. Dept. Geol. Sci. Bull., vol. 15, pp. 153–158, 1925.

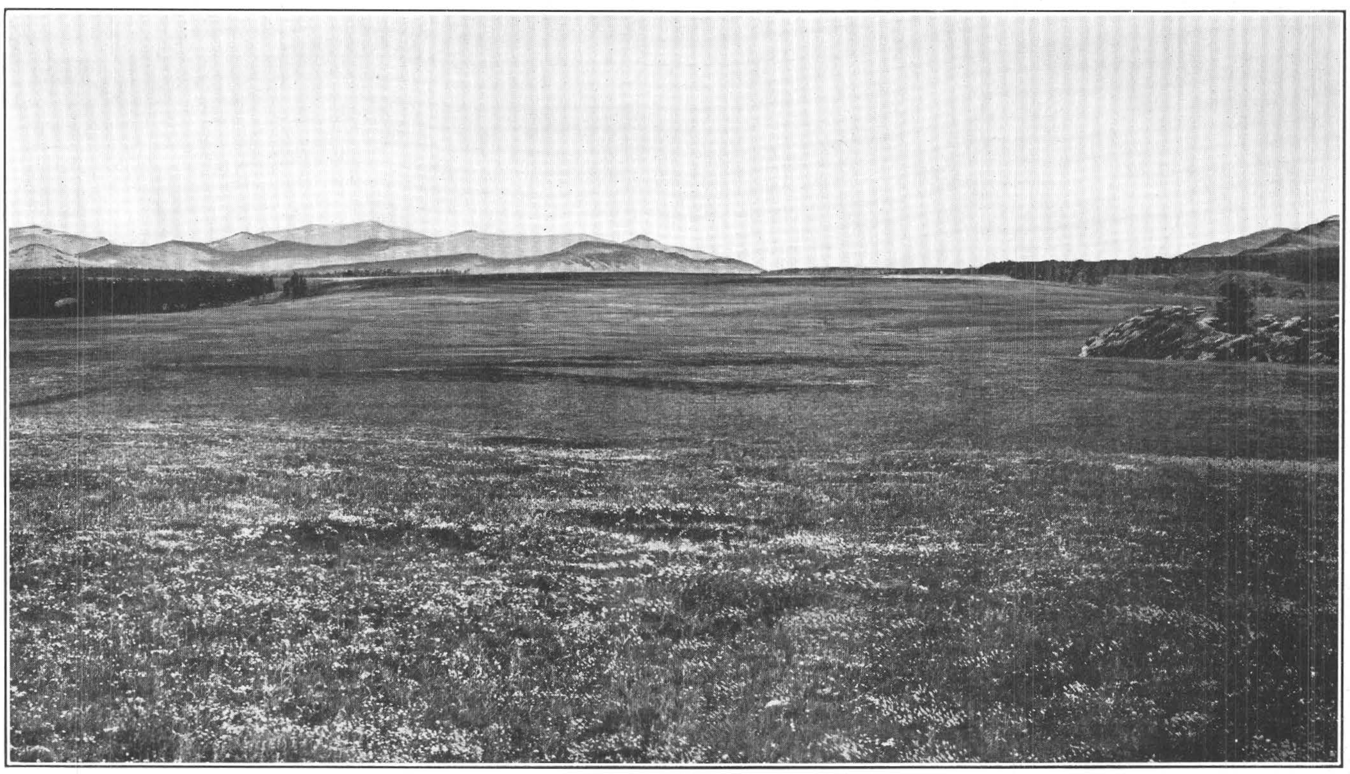
[12] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 7), 1899.

[13] Mansfield, G. R., Glaciation in the Crazy Mountains of Montana: Geol. Soc. America Bull., vol. 19, p. 564, 1907.



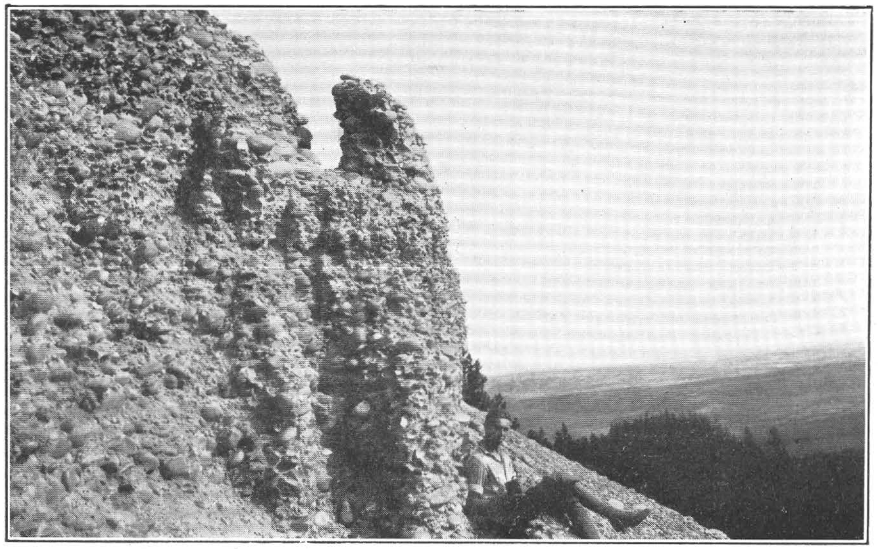
A. EAST FLATTOP MOUNTAIN, GLACIER NATIONAL PARK, MONT.

View south across Swift Current Valley. St. Mary Ridge, capped with pre-Wisconsin glacial drift, at the left. Photograph by Bailey Willis.



B. BIG HORN MOUNTAINS, WYO.

High plain of supposed Tertiary deposits, a part of the subsummit plateau. Near Canyon Creek, 10 miles west of Hazleton. Altitude 9,000 feet. Peaks of the central crest in background, 11,000 to 13,165 feet. Photograph by N. H. Darton.

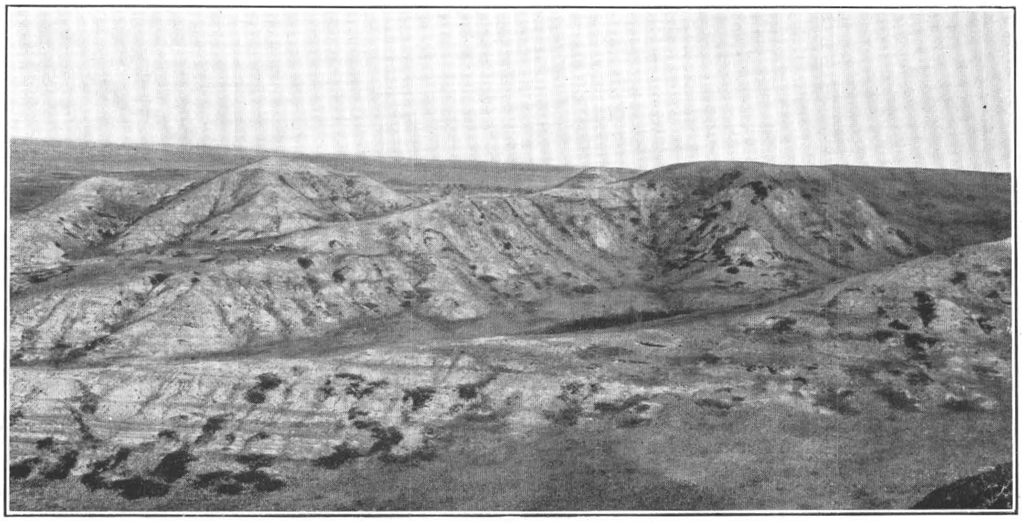


A. OLIGOCENE (?) CONGLOMERATE CAPPING CYPRESS HILLS, ALBERTA

Smooth waterworn pebbles, mostly quartzite.

B. WATERWORN QUARTZITE PEBBLES IN OLIGOCENE (?) GRAVEL CAPPING CYPRESS HILLS, ALBERTA

C. EASTERN EDGE OF BEARTOOTH PLATEAU, WYO., BETWEEN MONTANA-WYOMING LINE AND CLARK FORK OF THE YELLOWSTONE RIVER



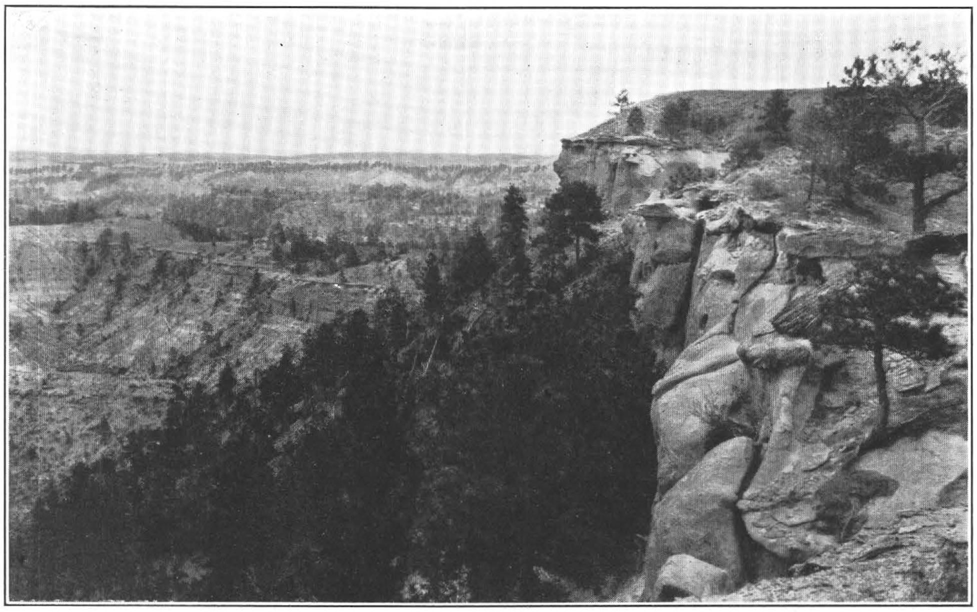
A

B

C

BIG SHEEP MOUNTAIN NORTHWEST OF TERRY, MONT.

Illustrating destruction of high gravel-covered benches and development of lower benches by erosion. *A*. Gravel-covered top of Big Sheep Mountain, at right; badlands on shale at left and below. *B*. Younger and lower gravelly bench being trenched by recent drainage. *C*. Last stages of breaking down of a high-level plain by broadening of a lower plain and dissection of the divide, Cedar Creek Valley northwest of Terry, Mont.



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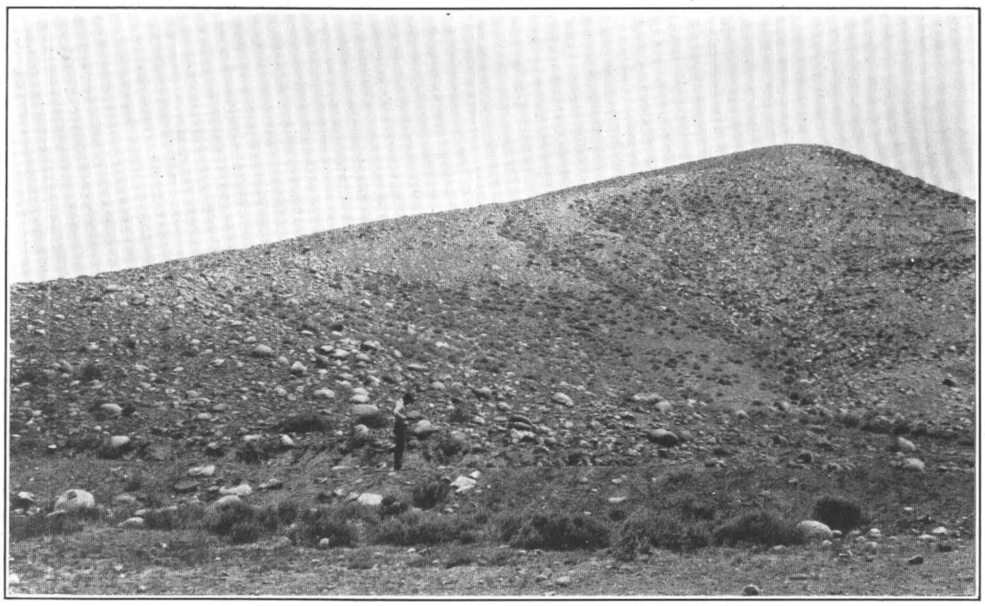


B

VIEWS ILLUSTRATING DESTRUCTION OF HIGH GRAVEL-COVERED TERRACES AND BENCHES AND DEVELOPMENT OF LOWER PLAINS AND GRAVELLY BENCHES BY EROSION

A. Gravel-capped Lance sandstone at right; badlands on dissected sandstone and shale at left. South of Myers, Mont., on the Yellowstone River. *B*. Pebbles and boulders moving down eroded shale slope from remnant of a gravel-capped terrace (No. 2 bench) at top of a hill northeast of Clark, Wyo.

The structure of the Absaroka Range, south of Livingston, as described by Weed,[14] is that of a broad anticlinal fold accompanied by minor crumples and modified more or less by profound faulting. The uplifted axis of this anticline is exposed in the high plateaus and mountains of Archean gneiss and crystalline schist. The edges of the Paleozoic strata are beveled off on each flank at or below the edge of the summit plateau, parts of which are designated East Boulder, West Boulder, and Lake Plateaus. This summit, though profoundly dissected by the branches of Boulder and other canyons, presents the appearance of a fairly uniform erosional plain as seen in a cross-country view from a high point. (See map of Livingston quadrangle.) The folded and faulted beds on the flanks include Cretaceous strata and that part of the overlying Livingston formation which is of Eocene age. From this it is evident that the summit plain is not older than Eocene, and it may be as much younger as Oligocene or Miocene. It is stated in the Livingston folio that

> The surface of the plateau of gneiss which is drained by the Boulder River and its tributaries appears to have been planed to the level of an ancient sea. The streams then flowing could cut no lower than their mouths, but the plateau has since been elevated with reference to the sea and is being carved by modern streams.

It should be remembered, however, that the shore of that sea was probably as far distant then as now.

The present rugged aspect of the topography on the east side of the Yellowstone Valley from Livingston south to Emigrant station, Mill Creek, and Mount Cowen is due largely to the spurs and reentrants of the dissected edge of this summit (or subsummit) plain as seen from below. That part north of Mill Creek culminating in Mount Cowen is in reality not higher than the broader plateau crests and peaks to the east.

A rugged strip between Stillwater and West Rosebud Canyons in the Beartooth National Forest north of Cooke, Mont., is known as the Granite Range. Some of the peaks, such as Mount Hague (11,200 feet) and Mount Wood (12,480 feet), rise above the broader parts of the crest, which is in reality one of the interstream segments of the great granite plateau. Another of the higher and smoother crests in southwestern Carbon County, shown on some maps as the Beartooth Plateau, stands 12,000 feet or more above sea level. From these high crests the observer may overlook a broad subsummit plateau, which constitutes the eastern peripheral part of the worn-off top of the range and to which the name Beartooth Plateau is here applied. (See pl. 3 *C*.)

The highest known remnants of the gravel-covered terraces along the Yellowstone River are those described on page 28 as truncating the crests of the ridges east of Billings (east and west of Pryor Creek), about 4,000 feet above sea level. The more westerly one is about 65 miles northeast of the edge of the Beartooth Plateau and about 1,000 feet above the Yellowstone River. To connect the plateau surface with this terrace remnant would require a steep stream gradient. It would extend the marginal slope of the plateau, which is fairly steep near the edge, outward some distance over the plains, and the gradient would decrease at a rate something like the following:

	Feet
5 miles, at 400 feet to the mile	2,000
5 miles, at 200 feet to the mile	1,000
10 miles, at 100 feet to the mile	1,000
20 miles, at 50 feet to the mile	1,000
25 miles, at 25 feet to the mile	625
Total descent (9,625 to 4,000 feet)	5,625

This gradient is high compared with that observed on the lower terraces of the same region, yet only that of the first few miles seems at all excessive. Perhaps so steep a gradient near the mountain front might be accounted for as the result of subsequent differential movement on the Beartooth fault in addition to general easterly tilting. Between 10 and 15 miles from the edge of the plateau, however, this gradient would have declined to 100 feet to the mile, and the plateau surface would have been only about 1,200 or 1,300 feet above the highest of the gravel-capped terraces now preserved in the region of Red Lodge.

The facts stated above, taken in connection with the other phenomena of the region described below, seems to the writer to make it unlikely that the Beartooth subsummit plateau is younger than Miocene, even if it is not so old as Oligocene. It resulted from long-continued erosion following the Heart Mountain overthrust, but whether or not the development of this plateau occurred prior or subsequent to the extrusion of the volcanic breccias of the Absaroka Range in late Miocene time, or whether or not the volcanic rocks extended northeastward over this plateau, is not known. If the volcanic rocks did so extend, the northeastward-flowing streams that now deeply dissect the plateau may have originated on the slopes of the old volcano, the remnant of the filling of whose throat constitutes the Crandall stock, a part of Hurricane Mesa[15] south of Clark Fork. There is considerable

[14] Iddings, J. P., and Weed, W. H., U. S. Geol. Survey Geol. Atlas, Livingston folio (No. 1), 1894. On the geologic maps in the Livingston folio this range is labeled "Snowy Range," but the name "Absaroka Range" was adopted by the United States Geographic Board. Geologists who studied the Livingston and adjacent quadrangles (Hague, Weed, Iddings, and others) appear not to have applied the name "Absaroka" to the mountains north of the Montana State line in their descriptions.

[15] Iddings, J. P., and others, Geology of Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, pp. 215–268, 1899. See also Hague, Arnold, U. S. Geol. Survey Geol. Atlas, Absaroka folio (No. 52), 1899.

volcanic material in the gravel capping the high ridges east of Billings, together with granite, purplish-red and yellow quartzites, quartz, agate, opal, chalcedony, and silicified wood. Some of this material, however, probably came down the Yellowstone from points farther west.

It is possible that some of the high-level gravel may have been deposited by Clark Fork when it was flowing in a more easterly course than now and traversing the gap at the west end of the Pryor Mountains, formerly followed by the Chicago, Burlington & Quincy Railroad, which is about 5,260 feet above sea level. This gap is about 45 miles northeast of that part of the edge of the plateau near the Clark Fork Canyon. In this distance, a stream on a gradient similar to that postulated above would be flowing at about the level of this pass, and streams west of the Pryor Mountains would be at levels higher than the tops of any of the ridges that now border the valley of Clark Fork on the east.

CHARACTER OF HIGH-LEVEL GRAVEL AND RELATIONS TO THE YELLOWSTONE TERRACES

GRAVEL ON TATMAN MOUNTAIN, WYOMING

A stream deposit farther south in the Big Horn Basin, which is probably of either Oligocene or Miocene age, is the cap of gravel on Tatman Mountain, 25 to 30 miles west of Basin, Wyo. This so-called mountain is an erosional remnant, or butte, composed of nearly flat-lying Tertiary shale and sandstone, which rises 1,200 to 1,300 feet above the Greybull River on the north. It was described by Fisher, and the fossil-bearing beds have been studied by Loomis, Sinclair, Granger, and others. The following statements are quoted from Sinclair and Granger:[16]

That the Tertiary infilling of the Big Horn Basin has been subjected to enormous erosion is at once apparent to an observer standing on the flat-topped summit of Tatman Mountain and looking off over the great depression of Buffalo Basin to the south or the valley of the Greybull to the north. Tatman Mountain, in reality only a residual butte spared by erosion, is capped by stream-worn andesitic gravels which may be of Oligocene age, as will be suggested later. The gravel sheet is underlain by about 600 feet of sandstone and lignitic shales in which no fossils have yet been found except leaf impressions, fresh-water mollusks, and Entomostraca. These rest conformably on the Wind River (*Lambdotherium* zone), and this, in turn, is in direct stratigraphic continuity with the Wasatch. As shown by remanie gravels at lower levels, derived from the deposit on Tatman Mountain, erosion has spared but a small part of this once extensive formation. As no fossils have yet been found in the gravels, their age is uncertain, but on the strength of certain lithologic similarities to be referred to later, they may be regarded as Oligocene, and the dissection of the Tertiary deposits of the Big Horn Basin fixed as later Oligocene and post-Oligocene. * * *

Tatman Mountain is capped by about 30 feet of stream gravels resting unconformably (?) on the lignitic shales below. While the majority of the pebbles are of volcanic rocks, no particularly careful search is necessary to demonstrate the presence of vein quartz and quartzite. As no fossils have yet been found in the Tatman Mountain gravels and nothing in the shales below but traces of plants and a few invertebrates, their age can not be fixed, and the questionable assumption that they are Oligocene is based entirely on their stratigraphic position above beds which may correspond to the so-called Bridger and perhaps also the known Uinta of the Wagonbed Spring section in the Wind River Basin. The exposures on Tatman Mountain are but fragments of a formation at one time more extensive but now almost entirely destroyed by erosion.

The gravel cap on Tatman Mountain is 5,800 to 5,850 feet above sea level; 30 to 35 miles to the west the worn-off tops of the Carter Mountains, spurs of the Absaroka Range, rise from the head of Meeteetse Rim to altitudes of 10,000 to 12,000 feet or more. These mountains are composed of volcanic breccias and one or more basalt flows. If they are the same as those in the continuation of the same ridge immediately to the west, in the southeastern part of the Ishawooa quadrangle,[17] they are of Miocene age. If the andesitic gravel capping Tatman Mountain came from this ridge it was probably deposited not earlier than Miocene time. The included quartzite pebbles may have been derived secondarily from Wasatch conglomerate, which crops out between Tatman Mountain and the mountains to the west. Where examined by the writer at the top of the bluff east of Meeteetse, the pebbles in this conglomerate consist almost wholly of smoothly waterworn quartzite, together with a small percentage of porphyry, limestone, quartz, and decomposing granite. No andesite or other volcanic rocks were found, though such rocks are abundantly represented in the later Tertiary and Pleistocene gravel of the Big Horn Basin. Apparently the andesitic pebbles in the gravel on Tatman Mountain could not have been derived from Wasatch conglomerate, but must have come from the Miocene volcanic rocks.

The Owl Creek Mountains, farther south, formerly called the Shoshone Mountains, which are at the headwaters of the Wood River, are said by Darton[18] to consist largely of agglomerate and lava flows, interbedded with sandstone and shale. In these mountains, near the head of the Middle Fork of Owl Creek, a large number of fossil leaves which were considered of Fort Union age were discovered in a shale in the interbedded mass. If this age determination is correct, some of the volcanic rocks here, as farther northwest in the Absaroka Range, are of early Tertiary age and possibly might have yielded andesite to the gravel

[16] Sinclair, W. J., and Granger, Walter, Eocene and Oligocene of the Wind River and Big Horn Basins: Am. Mus. Nat. Hist. Bull., vol. 30, pp. 87–88, 111, 1911. See also Sinclair, W. J., and Granger, Walter, Notes on the Tertiary deposits of the Big Horn Basin: Idem, vol. 31, pp. 57–67, 1912.

[17] U. S. Geol. Survey Geol. Atlas, Absaroka folio (No. 52), 1899.

[18] Darton, N. H., Geology of the Owl Creek Mountains: 59th Cong., 1st sess., S. Doc. 219, p. 25, pl. 10, *A*, 1906.

of Tatman Mountain in Oligocene time, if high enough in the mountain range.

A stream gradient projected eastward 30 to 35 miles from the edge of the smoothly worn top of the Carter Mountains, 10,000 feet above sea level, would coincide with the gravel cap of Tatman Mountain, if an initial slope of 250 feet to the mile is assumed to decrease gradually to a fall of about 40 feet to the mile. To judge from the grades of the lower terraces yet preserved in this basin, this would not have been an abnormally high gradient, inasmuch as it would have included the effects of post-Miocene differential elevation. Swinging toward the north as it joined the Big Horn River, the stream that deposited this gravel on Tatman Mountain would have had to cross the Sheep Mountain and Little Sheep Mountain anticlines and the great Pryor-Big Horn Mountain uplift. The relatively resistant limestone and sandstone in these mountains undoubtedly would have retarded erosion, and as a consequence a stream with a gradient of but 10 feet to the mile projected northward for the next 80 miles from the gravel on top of Tatman Mountain would have issued at 5,000 feet above sea level from the sag in whose bottom is cut the lower canyon of the Big Horn River. This is not far from the altitude of the Pryor Mountain gap (5,260 feet), to the west, and of the highest of the gravel remnants which Thom[19] found near the north flank of the Pryor Mountains and the northern part of the northeast flank of the Big Horn Mountains in Montana. (See p. 28.) A grade of 30 feet to the mile for the succeeding 35 miles would connect with the gravel-capped top of Pine Ridge between the converging Big Horn and Yellowstone Valleys.

HIGH GRAVEL NEAR THE YELLOWSTONE

The occurrence of gravel on Pine Ridge is described by Rogers[20] as follows:

Yellowstone and Big Horn Rivers meet at a rather acute angle, and Pine Ridge constitutes the high divide between them, the present shape and position of the ridge being controlled partly by the geology. The top of the ridge is remarkably level and rises only slightly to the south, maintaining an average height of about 1,100 feet above the rivers. Because of the level character of its crest and its thick covering of gravel it is believed to represent an old river terrace. In other words, at some time in the past the river beds must have been about 1,100 feet higher than at present, and the rivers, in meandering, deposited the gravel which now covers Pine Ridge. The ridge itself rises about 400 feet above the immediately surrounding country, and its level crest is in this district commonly less than 200 feet wide. Its slopes are everywhere steep and are broken into characteristic rounded hills. * * *.

[The gravel] is made up for the most part of pebbles from half an inch to 3 inches in diameter, although pebbles 6 or 8 inches in diameter are not rare. There is also an interstitial filling of fine gravel and sand. The thickness of the gravel is difficult to estimate, owing to the fact that it constantly slumps down, never forming cut banks. The thickness of 40 feet given in the columnar section probably represents a maximum, and the average thickness is probably less than 30 feet. As mentioned above, the gravel has exercised a distinct influence on the topography and drainage and is constantly being carried down and reworked by the streams which have their sources in Pine Ridge. Probably more than half of the gravel is composed of quartzite, chert, and other siliceous rocks, but a very wide range of igneous rocks also enters into its composition, and all the main types, from rhyolite to pyroxenite, have been observed by the writer.

At the time the above description was written but little was known concerning the relations of the terrace gravels of Montana and Wyoming, and Rogers's suggestion that this gravel is "either early Quaternary or possibly late Tertiary" was probably, in part at least, based on conference with the present writer. From consideration of the factors discussed in the present paper it now seems more probable that the gravel on Pine Ridge, as on the highest tops east and west of Pryor Creek, is to be correlated with the gravel on the Cypress Hills and Tatman Mountain as either Oligocene or Miocene.

The change in the projected gradient of this Oligocene or Miocene stage of the Big Horn River from 10 feet to the mile for the 80 miles between Tatman Mountain and the mouth of the lower canyon in Montana to an average of 30 feet for the 35 miles between the Canyon and Pine Ridge might possibly be accounted for as the result of a moderate uplift of the Pryor-Big Horn anticline, the effect of which would be to lessen the gradient of the Big Horn River in and above its lower canyon and to increase the gradient between the canyon and the Yellowstone River.

In a report on the Tullock Creek coal field, east of the Big Horn River, Rogers and Lee[21] describe gravel deposits, the highest and oldest of which are the equivalent of those on Pine Ridge. In this connection the present writer is cited by Rogers and Lee as if concurring in the suggestion that the highest of the gravel deposits in the Tullock Creek field may be Pleistocene. Though that citation might have been permissible at the time the Tullock Creek report was written, in 1913–14, it does not now agree with the writer's opinion, which is that the highest of these gravels, like those on Pine Ridge, may be as old as Miocene or Oligocene and may be equivalent to the gravel on the Cypress Hills. It is not clear from the descriptions given by Rogers and Lee whether or not remnants of the highest flat terraces are preserved on the divide between Tullock and Sarpy Creeks. Evidently most of the gravel has been let down from the

[19] Thom, W. T., jr., personal communication.

[20] Rogers, G. S., Geology and coal resources of the area southwest of Custer, Yellowstone and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 541, p. 317, 1914.

[21] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, pp. 44–47, 1923.

older and higher terraces by erosion. Apparently these deposits are remnants of the Flaxville and lower terraces. (See pp. 27–29.) The gravel is said not to extend more than 23 miles south of the Yellowstone River except on the western edge of the coal field, where it is found also in a zone extending about 10 miles back from the Big Horn River. The general altitude of the highest gravel is 3,700 to 3,800 feet above sea level, or 1,100 feet above the rivers. No fossils indicative of the age of the deposit were found.

The gravel of the Tullock Creek field is composed of pebbles representing a wide range of rock types. Quartzite is one of the most abundant—a fact which is no doubt due more to its greater hardness than to its preponderance in the original series of rocks from which the gravel was derived. Jasper and quartz are common, and chalcedony is also found. Pebbles of very dense fossiliferous limestone are present, and crinoid stems were noted in one pebble. Of igneous rocks a fairly complete series is present, the types ranging in composition from basalt to granite and in texture from porphyritic to granitic. Sandstone of the type common in the Cretaceous and Tertiary rocks of the region was rarely found. The pebbles are for the most part smoothly rounded and are ovoid to flattish in shape. They are fairly well sorted locally, the average diameter being 2 to 3 inches. Pebbles 6 inches in diameter are common, however, and a few boulders 10 to 14 inches in diameter were found. The interstitial material is chiefly quartz, generally in angular grains; very little clay is associated with the gravel.

Dobbin[22] describes high-level gravel south and east of Forsyth as follows:

OLIGOCENE OR MIOCENE (?) GRAVEL

The oldest gravel deposit in the field caps a plateau on the divide between Arnells and Sarpy Creeks in the northwest corner of T. 3 N., and the southwest corner of T. 4 N., R. 39 E. Gravel occurs at the same level on the tops of the highest hills and ridges in the northern part of T. 4 N., R. 41 E. These gravel deposits are but small remnants of a much larger river terrace and stand 1,050 to 1,100 feet above Yellowstone River. The gravel, which is 60 feet thick, is thoroughly cemented at the base into a conglomerate. The deposit contains boulders a foot or more in thickness and consists of igneous rocks ranging in composition from granite to basalt, particularly andesitic porphyries. Agate, silicified wood, and fragments of coal clinker occur in it, indicating that at least some of the coal had been burned along its outcrop before the gravel was deposited.

From the distribution of these highest terrace remnants it appears that the main stream of Oligocene or Miocene time may have flowed in a gravel-floored valley, 10 to 20 miles or more in width, south of the line of the present Yellowstone Valley between Billings and Miles City.

[22] Dobbin, C. E., The Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Mont.: U. S. Geol. Survey, Bull. 812, pp. 20–21, 1929.

High-level gravel on the top of Big Sheep Mountain, at the head of Cedar Creek, in T. 15 N., R. 47 E., in the northwestern part of Prairie County, was examined by the writer in 1922. This mountain is crossed by the Crowley road 25 or 30 miles northwest of Terry. The top, which is flat, constitutes the divide and the highest land in sight and is capped with 20 to 30 feet of coarse, well-rounded gravel with some included sand. (See pl. 4 *A*.) In places this gravel is cemented by calcium carbonate to a conglomerate. The largest stones noted were 6 by 10 inches in diameter. In lithologic character the pebbles are much the same as those on the lower benches, comprising several varieties of porphyry and other crystalline rocks, a few granites, numerous pink and reddish quartzites, vein quartz, chert, and silicified wood. No other fossils and no limestones were found. The notable thing about this deposit is its position and relatively high altitude: it is about 1,400 feet above the Yellowstone at Terry and 3,600 feet (barometric) above sea level. This altitude, if even approximately correct, is about 400 feet higher than that of the highest gravel found by Rogers on Little Sheep Mountain, a few miles to the south. The deposit is so much higher (600 to 800 feet) than the remnants of the Flaxville Plain in the Glendive quadrangle that it quite possibly belongs to an earlier stage. It may be of Miocene or Oligocene age. The nearest remnant of deposits which have been referred to the White River Oligocene caps Sentinel Butte, N. Dak. This point, which is a few miles south of the village of Sentinel Butte, on the Northern Pacific Railway and 10 miles east of the Montana-North Dakota State line, is about 90 miles from Big Sheep Mountain in a direction a little south of east. The top of Sentinel Butte is 3,430 feet above sea level, so that a grade of less than 2 feet to the mile would connect the two deposits.

No features of the plains of Montana or northern Wyoming rise above the projection of this supposed Oligocene or Miocene Cypress Plain, except the Sweet Grass Hills and outlying mountain groups and possibly the Bull Mountains, between the Yellowstone and Musselshell Rivers and the Wolf and Rosebud Mountains and similar ridges of Eocene rocks east of the Little Horn River.

MIOCENE AND PLIOCENE EPOCHS

FLAXVILLE PLAIN OR NO. 1 BENCH

The development of the Cypress Plain was followed by a regional uplift so that streams which had been shifting to and fro on this plain now cut deep valleys. As the land ceased to rise, or perhaps during intervals of cessation which alternated with periods of renewed uplift, the work of planation was begun and carried on. The amount of the uplift is indicated by the vertical distance between the Cypress Plain and the next lower plain (Flaxville Plain, or No. 1 bench [23]). This amounts to about 700 to 1,000 feet east of meridian 109° W. and 1,000 to 1,500 feet west of this meridian, possibly 2,000 feet in the Rocky Mountains of the Glacier National Park, and 3,000 feet or more northeast of the Yellowstone National Park.

The process of planation was not simply the development and extension of flood plains along the main streams and their tributaries. Every ravine contributed to the result. The region under description is mostly underlain by soft indurated clayey shales with interbedded friable sandstones. These porous sandstones, as also the Oligocene gravel, absorbed rain water and transmitted it, and where there edges cropped out in eroded slopes springs and seeps issued and moistened underlying Tertiary or Cretaceous clays. In such places landslides frequently occurred, the fine mud was readily carried away in suspension, and friable sandstone blocks slid down and crumbled to sand, which was later washed or blown away, and coarse gravel rolled and slid from the higher level onto the newly developed plain. By this process the steep marginal slopes below the gravel-capped interstream remnants of the Cypress Plain gradually receded, narrowing the divides and developing a new and lower set of valley plains that sloped gently to the main streams. (See pls. 4 and 5.) To the accumulation of secondary gravel let down from the Cypress Plain streams heading in the mountains made new contributions of similar gravel and sand brought directly from the mountains, and in these deposits accumulating on the land, along stream channels and flood plains and in ponds on the newly made plain, were entombed remains of animals that have been identified as "not older than Miocene or younger than lower Pliocene."

By the end of Miocene time or early in Pliocene time the process of peneplanation had proceeded so far and divides had been so much worn away that the whole of the northern Great Plains north of the Black Hills, the Big Horn Mountains, and the Belt Mountains presented the aspect of a peneplain with but few eminences rising above it. East of the front range of the Rocky Mountains the most prominent of these remnants were the Sweet Grass Hills and the Bearpaw, Little Rocky, Highwood, Moccasin, Judith, Big Snowy, and Crazy Mountains. The gravel cap of the Cypress Hills may have stood 1,000 feet or more above the surrounding plain, and off to the southeast in the Dakotas were the Killdeer Mountains, Sentinel Butte, and a few other like remnants of the Oligocene plain, with some in southeastern Montana. Cherrypatch Ridge, north of Harlem, in Blaine County, Mont., is one of the minor remnants from which most of the older gravel has been removed. It is not certain that the top of this ridge is as high as the Cypress Plain. Close to the mountain fronts great alluvial fans may have coalesced in one continuous flat, but farther out this split up into broad valley plains bordering the main streams and separated by low, worn-down divides—for example, the Bull Mountains.

The altitude of this plain in eastern Montana was perhaps about 2,000 to 2,500 feet, where now it is about 2,500 to 3,000 feet. The uplift was differential, increasing toward the west, so that at the mountain front in and south of the Blackfeet Indian Reservation the altitude was probably about 4,500 feet where now it is about 6,000 feet.

The most extensive remnants of the Miocene or Pliocene plain and the gravel and sand thereon are north of Missouri River, in the northeastern parts of Blaine and Valley Counties and what are now Daniels and Roosevelt Counties, Mont. They comprise a total area of about 1,800 square miles and have been studied by Collier and Thom,[24] who described them as Flaxville gravel. It was here that evidence of the age of this plain was found. From the Flaxville gravel Collier and Thom collected fossils which were identified by Gidley as remains of several forms of the three-toed horse, horned gopher, rabbit, rhinoceros, creodont, camel, saber-tooth tiger, a doglike animal, and fish. Concerning these fossils Gidley made the following statement:

> None of the material is sufficiently good or complete to make positive specific determinations, and it is therefore of no value as indicating horizon, except in a broad way. With the exception of the specimen reported as Pleistocene, all the material appears to belong to the upper Miocene. It can be stated positively, I think, that with the exception noted the beds from which these fragments were collected can not be older than Miocene or younger than lower Pliocene.

Further details concerning the fossils are given in Collier and Thom's paper.

AGE AND CORRELATION OF THE FLAXVILLE TERRACES OR NO. 1 BENCHES

The fossils as identified by Gidley seem to afford ground for concluding, at least tentatively, that fluvial deposition continued on the Flaxville Plain into Plio-

[23] Obviously there are some objections to applying serial numbers to the several sets of remnants of these dissected ancient plains, benches, and terraces; on the other hand, there are equally strong though somewhat different objections to applying names instead of numbers to these features, many of which already carry local names. After careful consideration of the various objections and advantages, the writer has adopted the plan of using the names "Cypress Plain" (Oligocene or Miocene) and "Flaxville Plain" (Miocene or Pliocene) and of numbering the Flaxville and the set of probable correlated remnants as No. 1 and the lower and younger sets of remnants, in order downward, as No. 2 and No. 3. It is hoped that these designations will be fairly clear to the reader without more detailed statements.

[24] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1918. Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120, pp. 17–39, 1918.

cene and possibly even into early Pleistocene time, as remains of a Pleistocene camel were found.[25] Unfortunately, with one exception, no fossils have been found on any other remnants of this or the lower and younger sets of benches. The correlations presented in this paper are based almost wholly on physiographic relations and the relations of this surface to the glacial drift. As shown on the map, the benches surrounding the Bearpaw and Little Rocky Mountains lie midway between the remnant of the Flaxville Plain north of Harlem and remnants of similar benches comprising three sets in the Judith River Basin and about the flanks of the surrounding mountains. Correlation may also be made from the Missouri Valley in Sheridan and Roosevelt Counties across to three similar sets of benches or terraces on the lower Yellowstone in the Glendive quadrangle. As shown on the map and as described below, very meager and widely scattered remnants of No. 1 bench have been found along this valley, but the next younger and lower bench, or the second set of remnants of terraces, can be traced almost all the way up the Yellowstone to the mountains, though with numerous but shorter intervals where it has been cut away. The second set of remnants (No. 2 bench) can also be correlated fairly well northward along the mountain fronts and across the upper Musselshell Valley to the Judith Basin and thence westward past Great Falls, up the Sun River, and northward along the mountain front to the region of Glacier National Park. At intervals throughout this great extent of hundreds of miles isolated remnants of a higher set of gravel-capped benches are found, and these are consequently regarded as correlatives of the Flaxville Plain and are grouped together as No. 1 bench. These relations should be borne in mind in reading the following description of the Flaxville terraces.

FLAXVILLE PLAIN (NO. 1 BENCH) BORDERING ROCKY MOUNTAIN FRONT

For 175 miles west from Cherrypatch Ridge, in R. 21 E., Blaine County, to R. 8 W., in the Blackfeet Indian Reservation, Glacier County, degradation has destroyed the smooth gravelly Miocene or Pliocene plain and developed a lower and more uneven plain. In R. 8 W. are two small gravel-capped remnants, Landslide Butte and Horsethief Ridge, at 4,650 feet above sea level, and 10 to 15 miles further west and northwest larger remnants are found in the form of high gravel-capped benches or plateaus whose nearly flat surfaces rise gradually toward the mountain front in Glacier National Park. The deposits on these high benches have been studied and described by the writer and Stebinger.[26] The significance of certain very old deposits of drift of the mountain glaciers found on these benches near the mountain front is discussed in a subsequent connection (p. 31). The presence of this drift and the absence of fossils render the correlation of these high bench remnants with the Flaxville Plain of northeastern Montana somewhat uncertain.

It is possible that the top of Milk River Ridge (4,100–4,300 feet above sea level (?)) in the Warner and Cardston districts, southern Alberta, in T. 3 N., Rs. 17–21 W., is to be correlated with the highest benches south of the international boundary in the Blackfeet Indian Reservation, though it appears to have been cut down to a somewhat lower level, and inquiries and a partial examination of the east end of the plateau by the writer in 1920 seem to indicate that no Miocene or Pliocene gravel occurs in place on this upland beneath the glacial drift.

The most easterly large remnant of a high gravel-capped bench, other than Landslide Butte and Horsethief Ridge, is between the North and South Forks of the Milk River in T. 11 N., Rs. 21 and 22 W., in the Cardston district, southern Alberta, whence it extends across the international boundary into the Blackfeet Indian Reservation, Mont., in the northeastern part of the Blackfoot quadrangle, T. 37 N., R. 9 W. This is just outside the limit of continental glaciation, as the northeastern glacial drift at this place does not extend south of the North Fork Valley. At the international boundary this bench is 4,360 feet above sea level—that is, more than 300 feet above the branches of the Milk River to the north and south. Thence southwest and west to the mountain front there are many well-preserved flat-topped, gravel-capped remnants of former high-level plains, covering a total area of about 100 square miles. These mesas, which now stand hundreds of feet above the present streams, are all that remain of vast, remarkably smooth, gently sloping coalescent alluvial fans, which in a former age bordered the whole eastern front of the Rocky Mountains far to the south, extending from the international boundary and probably also some distance to the north. On the interpretation of the relations of these benches or plateaus depends much of our knowledge of the Cenozoic history of this whole region, both of the mountains and of the Great Plains. Study of relative altitudes of the several high-level tracts shows that they comprise two sets, a higher and a lower, separated by a vertical dis-

[25] Hay, O. P., The Pleistocene of the middle region of North America and its vertebrated animals: Carnegie Inst. Washington Pub. 322A, p. 169, 1924. Dr. Hay states, concerning this supposed Pleistocene camel: "The geologists at present regard the formation as being of late Miocene or early Pliocene. There may, therefore, be some error about the specimen of *Camelops*."

[26] Alden, W. C., Pre-Wisconsin glacial drift in the region of Glacier National Park, Mont.: Geol. Soc. America Bull., vol. 23, pp. 687–708, 1912. Alden, W. C., and Stebinger, Eugene, idem, vol. 24, pp. 529–572, 1913. Alden, W. C., Early Pleistocene glaciation in the Rocky Mountains of Glacier National Park, Mont.: Internat. Geol. Cong., 12th sess., Canada, 1913, Compt. rend., pp. 479–484, 1914.

tance ranging from 100 to several hundred feet—that is, they comprise remnants of a higher or older and a lower or younger gently sloping alluvial plain. The vertical interval by which they are separated is due to erosion. For convenience, as indicated, these may be designated respectively No. 1 bench (the higher) and No. 2 bench. A still lower bench (No. 3) is described below (p. 59).

If there are bordering the mountain front any representatives of the Flaxville Plain (Miocene or Pliocene) to be correlated with those in northeastern Montana, they are these remnants of No. 1 bench. No fossils have been found in the gravel on this bench, and there are undoubted evidences of the extension of very old glaciers from the mountains out onto the bench, so that, as described below (p. 32), it is possible that the streams were still flowing on No. 1 bench in early Pleistocene time. It may be stated, however, in advance of further discussion of the subject, that it is the writer's opinion, after such field studies as he has made in the valleys of the upper Missouri and the Yellowstone and their tributaries in Montana and Wyoming, that the highest benches now preserved near the mountain fronts in the region under consideration are correlatives of the Flaxville Plain.

In several places in the Blackfeet Indian Reservation, in Glacier County, remnants of both No. 1 and No. 2 benches are preserved on the top of a single interstream ridge. Bench No. 1 rises toward the mountain front from an altitude of about 4,700 feet in T. 37 N., R. 10 W., at an average rate of 100 feet to the mile (increasing in places from about 40 feet at the east to 200 feet at the west), and reaches 5,950 feet above sea level on Kennedy Ridge, east of Chief Mountain; 6,200 feet on Swiftcurrent Ridge, on the north side of Swiftcurrent Valley; 6,400 feet on Boulder Ridge, on the south side of that valley; 6,100 feet on St. Mary Ridge, east of Lower St. Mary Lake; and 6,200 feet on Two Medicine Ridge, north of Lower Two Medicine Lake. No. 1 bench is also probably represented by the top of Makowan Butte (Lee Ridge), at 5,800 to 6,000 feet, northwest of Chief Mountain in Waterton Lakes Park, Alberta, on the east side of the Belly River. On most of the ridges near the mountain front the upper 100 to 250 feet of the height is due to a thick deposit of glacial drift.

Each of these remnants is capped with a deposit of coarse gravel, predominantly quartzite and argillite. The stones are partly subangular and partly smoothly rounded. The larger stones are 10 to 12 inches in maximum diameter, as far east as Landslide Butte. The maximum size increases westward from this locality to points where relations are complicated by the deposits of old glacial drift, with its content of small and large faceted and striated boulders.

There are no remnants of No. 1 and No. 2 benches between the Great Northern Railway and the south side of the Two Medicine River Basin. About 25 miles southeast of Browning the " Y. G. B. line " or Park to Park Highway, traverses a notch in the crest of the high flat-topped gravel-capped divide between Badger and Birch Creeks.[27]

As would be expected from the fact that the Paleozoic limestones form so large a part of the more easterly mountain ridges south of Theodore Roosevelt Pass[28] (Marias Pass), the pebbles on this and all the similar gravel-capped ridges to the south are predominantly of limestone. From this ridge southward to the Sun River Basin and thence eastward to the region of Great Falls there are numerous remnants of No. 1 and No. 2 benches.[29] The grade of No. 1 bench as preserved on the divide between Badger and Birch Creek rises southwestward 300 feet in 7 miles, from 4,200 to 4,500 feet above sea level (more than 40 feet to the mile), and reaches 5,200 feet on a small crest 2 miles northeast of Heart Butte, a further rise of 700 feet in 12 miles (nearly 60 feet to the mile). The ridge south of Dupuyer Creek rises southwestward from 4,500 to 5,200 feet above sea level, or 700 feet in 8 miles, and reaches the mountain front at 5,900 feet above sea level east of Dupuyer Mountain, a further rise of 700 feet in 4 miles.

Pendroy, the terminus in 1920 of a branch of the Great Northern Railway, stands on one of the larger remnants of No. 1 bench. The flat surface of this gravel-covered bench rises westward from an altitude of 4,000 feet (barometric) near the east end to 4,300 feet at Pendroy and nearly to 4,600 feet at the Park to Park Highway near the west end, a rise of 600 feet in 14 miles (nearly 43 feet to the mile). If this gradient is projected westward 14 miles to the mountain front, without increase, it rises to 5,200 feet above sea level. Undoubtedly, however, the grade was considerably steeper toward the mountain front, and the bench may have reached an altitude of 6,000 feet. Some road cuts on this bench near Pendroy expose 5 feet or more gravel below the thin loamy soil. The pebbles range in length from a fraction of an inch to 8 or 10 inches and are fairly well rounded. Most of their surfaces are either coated with calcium carbonate or have been etched by solution. The pebbles consist

[27] Most of the data concerning the bench gravel between Badger Creek on the north and the Sun River on the south, both in and east of the Heart Butte and Saypo quadrangles, are taken from the field maps and notes of Eugene Stebinger and M. I. Goldman. (See also U. S. Geol. Survey Bull. 691, pl. 24, 1919.) Only a small part of these deposits has been examined closely by the writer.

[28] The name " Theodore Roosevelt Pass " was adopted June 2, 1920, by the United States Geographic Board for the pass in the Rocky Mountains traversed by the Great Northern Railway between Glacier Park Station and Belton, Mont. The name Marias Pass is applied only to the pass at Summit Station on the Continental Divide.

[29] Fisher, C. A., Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, pp. 24–25, pl. 1, 1909.

principally of gray limestone with a small percentage of dense green argillite and sandstone.

About 20 to 25 miles southeast of Pendroy, in T. 24 N., Rs. 2 and 3 W., is a narrow isolated remnant of No. 1 bench rising about 800 feet above the Teton River on the north. This is known as Teton Ridge, or T. L. Ridge. The western part of its gravel top is 4,340 feet above sea level.[30] The margin of the continental glacial drift lies along the north slope of the ridge up to about 3,900 feet (barometric), and above this is the narrow, flat gravel cap. A large part of the pebbles here consist of limestone with etched surfaces, and a large part of reddish or greenish sandstone and argillite.

That No. 1 bench on Teton Ridge originally extended much farther east appears probable from the fact that similar gravel was found capping one of the higher hills on the divide at a point 15 miles north of Great Falls at an altitude of about 3,900 feet (barometric), near but above the limit of the glacial drift. Other parts of this divide were not examined.

Certain buttelike remnants of higher levels on the divide between the Teton and Marias Rivers, 25 to 45 miles east of Brady, rise to about 3,500 or 3,600 feet (barometric). The tops examined by the writer in 1921 and by Collier in 1923 are thinly covered with continental glacial drift, but no bench gravel was seen. They are protected by caps of flat-lying sandstone overlying the shale and may have no definite relation to the plane of No. 1 bench.

About 30 miles west of Teton Ridge, in the Saypo quadrangle, T. 23 N., R. 8 W., is Long Ridge, a remnant of No. 1 bench 3 miles from the mountain front, which reaches 5,500 feet above sea level and stands 500 feet above No. 2 bench and 800 feet above Deep Creek, 1 mile to the south. The grade from the top of Teton Ridge to the top of Long Ridge is about 37 feet to the mile. This bench probably reached the mountain front at the bottom of the broad sag cut in the limestone wall, which was later trenched by the sharp, narrow gorge of the South Fork of Deep Creek.

On the divide between Deep Creek and the Sun River in T. 22 N., R. 6 W., between 5 and 25 miles southwest of Choteau, are remnants of No. 1 and No. 2 benches. In sec. 3, T. 22 N., R. 7 W., the west end of the bold plateau rises to 4,800 feet above sea level, or over 800 feet above the Sun River. The terminal moraine of the Sun River Glacier of the Wisconsin stage skirts the marginal slope up to 4,600 feet above sea level and in this moraine is cut the Sun River Slope Canal of the irrigation project. The divide is capped with coarse gravel and its flat top is thinly covered with loamy soil.

[30] Fisher, C. A., Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, pl. 1, 1909.

The pebbles, which range in size from a fraction of an inch to 1½ feet, consist of gray to brown limestone and red to brown quartzite and argillite, with perhaps some crystalline rocks. A sight taken westward along the smooth, gently sloping top of this ridge from a point 8 miles east of the west end of the bench showed that the gradient of the top projected to the mountain front across the interval of 13 miles, where the bench has been cut away by erosion, would reach the mountains at the bottom of the sag 4 miles wide in the limestone wall, in which is cut the sharp inner 1,000-foot gorge from which the Sun River issues. (See pl. 7 *A*.) This relation is of importance as one indication of the horizon (5,300–5,500 feet) at which Sun River was issuing from the mountains when No. 1 bench was formed. That horizon is about 1,200 feet above the present bed of the stream below the dam. The northeast end of No. 1 bench, which has been truncated by erosion, is near Priest Buttes, south of Choteau. Bordering the highest part of the crest on the south and east are several steplike drops, and the main one of these lower levels is probably the No. 2 bench.

A remnant of No. 1 bench, at an altitude of 3,900 to 4,000 feet (barometric), is the narrow gravel-capped flat top of the ridge north of the Sun River between 20 and 30 miles west of Great Falls. This is crossed by the Custer Battlefield Highway north of Ashuelot, which stands on No. 2 bench at 3,700 to 3,800 feet (barometric). The broad plain known as Greenfields Bench, between this ridge and Teton Ridge, to the north, is an undulating surface perhaps due to erosion of No. 1 bench but is not itself a definite bench of the gravel-covered type under description. The same is true of its eastward continuation, east of Gordon and Power, on which is the Benton Lake Reservoir, north of Great Falls. The remnant of a high bench at 4,600 to 4,700 feet, 5 to 7 miles west of Augusta, is probably part of No. 2 bench. Though this was high enough to stop the advance of the Sun River and Smith Creek glaciers in late Pleistocene time, it is probable that No. 1 bench before being removed by erosion was relatively still higher.

About 12 miles south of Augusta, in T. 18 N., R. 6 W., there is a small remnant of what appears to be No. 1 bench. This bench, which is a few miles northeast of Bean Lake, on the south side of the upper Flat Creek Valley, at 4,740 feet above sea level (barometric), is capped with a bed of coarse gravel, in which the pebbles consist of limestone, quartzite, and igneous rocks derived from the mountains to the west on the Dearborn River. The tops of the ridges to the north rise but little if at all above the plane of this No. 1 bench, but those along Birdtail Divide, to the east, rise much higher. The lower bench crossed by the moraines of the Dearborn River glacier is probably No. 2. At the time No. 1 bench was being formed the Dearborn River was probably flowing on the bottom of the broad sag at the mountain front, now represented by the bench or shoulder above the inner gorge. There are remnants of benches on the Middle and South Forks of the Dearborn River just east of the mountain front, but it is not known that any of these are as high as No. 1 bench. Possibly No. 1 bench is represented by the top of the caps of igneous rock on Fort Shaw, Crown, and Square Buttes at 4,500 feet above sea level, or 1,000 feet above the Sun River.

In this connection mention may be made of a high-level gravel deposit farther up the Missouri drainage basin in the angle between Canyon and Little Prickly Pear Creeks, about 25 miles northwest of Helena. This gravel deposit, which is, perhaps, to be correlated with No. 1 bench, was described some years ago by Barrell.[31] It caps a ridge a little more than 4 miles long, known as the Gravel Range, whose crest slopes somewhat north of east from an altitude of about 5,650 feet to about 4,700 feet at the top of the bluff, at whose base the automobile road runs up Canyon Creek. The bouldery gravel is reported by Barrell to be 500 feet thick on the western part of the ridge. On climbing the head or west end of the ridge, which rises about 1,000 feet above Little Prickly Pear Creek on the south, the present writer, in 1923, found the steep upper slopes and top covered with gravel and boulders, many of them 3 to 6 feet in maximum diameter, mostly of red and pink quartzite, with some purple, greenish, and yellow, together with irregular masses of andesitic lava. Although the stones are fairly well rounded and no glacial striae were seen, the abundance of large boulders suggests the possibility that an early Pleistocene glacier may have assisted in the transportation from the parent ledges. The material may, however, be a torrential stream deposit formed when the valley bottom was higher than the tops of the present shaly hills between this locality and the head of the basin to the southwest. Farther east the stones are not so large and the deposit is seen to overlie shale and andesitic lava, though large masses of the rock project above the gravel. Barrell describes residual masses of conglomerate composed of this gravel, cemented with silica, as capping smaller hills and lying on slopes to the south. Those on the slopes doubtless slid down from higher levels as the underlying shale slumped or was washed away. From the relations of similar high-level deposits described in this paper it may be inferred that this bouldery gravel represents stream deposition at the mountain fronts near the end of Tertiary time or the beginning of Pleistocene time. It is not known whether or not Little Prickly Pear Creek was then tributary to the Missouri River. Reasoning from the relations of fossiliferous Tertiary beds in the Missouri River and Smith River Valleys to the east, Barrell concluded that "these ancient gravels are certainly Tertiary, and probably not far from the end of the Miocene." To the present writer it seems more probable that if this bouldery gravel is not wholly or in part the product of an early Pleistocene glacier, it is not older than Pliocene, and that its deposition was later than the faulting, tilting, and erosion of the Bozeman beds. This relation can not, however, be demonstrated at this place.

Apparently No. 1 bench, if it ever bordered the Belt Mountains south of Great Falls, as it probably did, has been entirely eroded, at least no bench gravel was found on top of the foothills, which were examined up to 5,000 feet above sea level.

The top of Belt Butte (4,700 feet), 20 miles southeast of Great Falls, must be as high as the level of No. 1 bench, but there is no gravel upon it. Eight miles northeast of Belt Butte is a small mesa at 4,100 feet (barometric) near the Upper Highwood Road. This is capped with a deposit of pebbles and boulders as much as 2 feet in length. These stones are totally different from those on the high benches described above and consist of igneous rocks derived from the Highwood Mountains, to the east. The stones are partly subangular and partly well rounded, and appear to represent a torrential fan deposited by Highwood Creek when it flowed at a level 400 or 500 feet above its present channel. Possibly this deposit belongs to No. 2 bench, rather than No. 1. Examination of the top of Shepard Butte, which rises to 3,850 feet above sea level 2 miles northwest of Waltham, revealed no bench gravel but only thin glacial drift on the shale and sandstone.

To one who has examined the remarkably well-preserved alluvial benches of the Judith River Basin, which head on the foothills of the Moccasin, Big Snowy, Little Belt, and Highwood Mountains, there seems little doubt that the high gravel benches described above are remnants of vast ancient alluvial fans, which near the mountains probably coalesced in one nearly continuous alluvial plain of remarkable smoothness. The several components of this plain headed at the mouths of the mountain gorges, at an altitude now ranging from about 5,500 to 6,000 feet or more above sea level, and the resulting plain sloped eastward and northeastward along lines converging in a general way to the bend of the ancient Missouri River channel (now Milk River Valley) north of the Bearpaw Mountains, in the region of Havre. There was an initial slope near the mountains of 100 to 200 feet or more to the mile, which gradually flattened to less than 40 feet in the first 12 to 15 miles. Some

[31] Barrell, Joseph, Geology of the Marysville mining district, Mont.: U. S. Geol. Survey Prof. Paper 57, pp. 10–11, 34–38, 1907.

small remnants are preserved as much as 35 or 40 miles from the mountain front. Beyond this all traces have been cut away by erosion as far east as Harlem. If this plain was developed contemporaneously with the Flaxville Plain farther east, it sloped to a level which is now about 3,000 feet above the sea in the region of Harlem—that is, to an altitude corresponding to the Twete Plain, north of Harlem, about 650 feet above the level of the Milk River. This would be an average slope ranging from 7.4 to 9 feet to the mile across an area 160 to 180 miles wide, where no remnants of No. 1 bench are preserved. Most of this lower eroded area is now covered by glacial drift, so that it is not evident just how far the alluvial gravel extended.

From 7 to 9 feet to the mile is a gradient for streams flowing in narrow valleys or canyons, and such streams readily transport coarse material. These streams, however, were not flowing in canyons beyond the mountain fronts but were doubtless subdivided into numerous distributaries, which constantly shifted their courses from side to side on the great alluvial fans as the channels became blocked by débris.

FLAXVILLE PLAIN IN BLAINE COUNTY

No remnant of the Flaxville Plain closely borders the Milk River or the Missouri River east of Havre. South of Harlem, in and adjacent to the Fort Belknap Indian Reservation, are notable remnants of gravel-capped benches about the flanks of the Little Rocky Mountains, which are similar to those in the Blackfeet Indian Reservation, above described.

North of Harlem, in the northeastern part of Blaine County and the northwestern part of Phillips County, is an extensive, nearly flat plain underlain by 40 to 70 feet or more of gravel, in which were found some of the Miocene or Pliocene fossils described by Collier and Thom.[32] This plain, as mapped in the northeastern part of the Cherry Ridge quadrangle, has a general altitude of 3,000 to 3,200 feet. Northeast of Woody Island Coulee it is buried beneath a great deposit of morainal glacial drift. The plain is bordered on the west by Cherrypatch Ridge, whose dissected slopes rise to a crest 3,300 to 3,500 feet above sea level. This ridge, which separates the gravel plain from the Milk River Valley, curves southeastward, and in Ts. 34 and 35 N., Rs. 22–25 E., is replaced by or buried beneath a broad belt of knobby terminal moraine. This is all a part of what McConnell [33] designated the Boundary Plateau.

The position and trend of Cherrypatch Ridge suggest that it is a worn-down spur of the Cypress Hills Plateau. It is capped with coarse gravel and conglomerate, whose pebbles are mostly less than 3 inches in diameter but with many 6 to 12 inches. The materials are mostly reddish, brownish, and greenish argillite and quartzite, with some diorite and amygdaloidal lava similar to the rocks of Glacier National Park. The presence of Cherrypatch Ridge, separating the Flaxville gravel on the northeast from the Milk River Valley, shows that this gravel could not have been washed out directly from the mountains 200 miles or more to the west. Apparently it must have been let down from higher levels by erosion, in the process of peneplanation described above (p. 13) or have been washed southeastward along a broad basin from the Cypress Hills Plateau, 50 to 75 miles to the north and northwest.

BEARPAW MOUNTAINS AND NO. 1 BENCH

The highest peaks of the Bearpaw Mountains, 25 miles south of Havre, reach altitudes of about 7,000 feet—that is, 3,000 to 4,000 feet above the immediately surrounding plain. The Missouri River in later Tertiary time is believed to have flowed northeastward on the west side of the Bearpaw Mountains to the vicinity of Havre, along the course now followed by Sandy Creek, and thence to have flowed eastward along the course of the present Milk River.[34] The Bearpaw Mountains were therefore subject to rapid and prolonged erosion by numerous streams rushing down to the Missouri. The mountain mass and the bordering foothills were, in consequence, deeply dissected and much worn down. The tops of only a few of the foothills have been examined by the writer.

The Bearpaw Mountains and most of the area between these mountains, the Little Rocky Mountains, and the Missouri River were mapped by Reeves [35] in 1922 and 1923, and to him the present writer is indebted for the location, extent, and differentiation of remnants of benches shown on Plate 1. Reeves also completed the mapping of some of those traversed by the writer east of Cow Creek, which head in the Little Rocky Mountains. In the area west of Cow Creek he found remnants (some of them extensive) of three sets of benches, which headed in the Bearpaw Mountains and which are probably to be correlated with the three sets heading in the Little Rocky Mountains, to the east. These benches were all developed and probably all dissected before the invasion of the ice, which shifted the Missouri River from the north

[32] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 180–181, 1918.

[33] McConnell, R. G., On the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, p. 44, 1886.

[34] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, pp. 34–45, 1906.

[35] Reeves, Frank, Geology and possible oil and gas resources of the faulted area south of the Bearpaw Mountains, Montana: U. S. Geol. Survey Bull. 751, pp. 76–77, pl. 13, 1924.

to the south side of the Bearpaw and Little Rocky Mountains. The largest remnant of No. 1 bench (Lone Tree Bench) is between Black Coulee and Bullwhacker Creek. It is about 15 square miles in extent and covers adjacent parts of Ts. 24 and 25 N., Rs. 18 and 19 E. It slopes gently southward from an altitude of 3,588 feet at the north to an abrupt dissected margin nearly 1,000 feet above the level at which the Missouri River now flows in a narrow gorge 3 miles farther south. Another small remnant of No. 1 bench, about 12 miles farther northeast and nearer the mountains, has an altitude of 3,876 feet. Three small remnants of a high gravel bench found by Reeves at the north front of the mountains west of Lloyd and one at the west side of the mountains northwest of Centennial Mountain, at about 3,600 feet above sea level, may also correspond to the Flaxville Plain.

Bowen[36] mapped the boundary of the areas "covered by drift or bench gravel" east of the Bearpaw Mountains, but did not differentiate the several benches.

LITTLE ROCKY MOUNTAINS AND NO. 1 BENCH

As stated above, there are no remnants of the Flaxville Plain closely bordering the Milk River Valley east of Havre, but 35 to 40 miles south of Harlem, in the Fort Belknap Indian Reservation, notable remnants of gravel-capped benches encircle the Little Rocky Mountains. A downward slope of about 10 feet to the mile would connect the highest of those bordering the north slope with the supposed level of the former Flaxville Plain where now is the Milk River Valley near Harlem.

Though deeply dissected, the Little Rocky Mountains appear much less worn down than their neighbors, the Bearpaw Mountains. The higher peaks, carved from the central mass of crystalline rock, rise to altitudes of 6,000 feet or more—that is, 2,500 to 3,000 feet above the adjacent plain. Surrounding the crystalline core are the upturned edges of Paleozoic limestone and Mesozoic sandstone and shale. Wearing away of the shale leaves the edges of the sandstone projecting in places as hogback ridges or foothills, whereas the massive limestone forms a great encircling mountain wall hundreds of feet in height. (See pl. 6.) This wall is breached at intervals by picturesque gorges cut by outflowing streams. Beveled across the edges of the upturned shale and sandstone are remnants of smooth, gently sloping benches. (See pl. 35.) These comprise three distinct sets so similar in their character and topographic relations to those described above as bordering the Rocky Mountain front and also to those farther east on the Missouri River that their contemporaneity of formation seems fairly certain. The thin soil on these benches is underlain by coarse gravel composed entirely of rock from the local mountain mass, except in those places where the benches were overridden by the continental ice sheet, in which pebbles and boulders of granite and other rocks from Canada occur on the surface. No evidence of local glaciation of the mountains has been found.

The grade of the highest bench (No. 1) in the vicinity of Lodgepole, if projected to the mountain slope across an interval where the bench has been eroded, leads to the general level of the top of the great limestone wall, and north and west of St. Paul's Mission are remnants which yet retain their connection with the top of this wall. (See pls. 7 *B* and 8.) The relation of No. 1 bench to the truncated edges of the limestone formations and to the general profile of the smoothly worn slopes and crests of the mountains above shows that the great alluvial fans, of which these benches are remnants, were the product of a long period of degradation.

Large remnants of this bench, one of them 7 miles in length, lie east and north of the village of Lodgepole on both sides of a valley 300 feet deep, which was perhaps that of Lodgepole Creek before it was blocked by glacial drift. The thin soil on this bench is underlain by coarse gravel, and the smooth, flat top rises toward the mountains with a grade increasing from 50 to 100 feet to the mile. These grades if projected, with normal steepening, across intervals 2 to 3½ miles wide, where the bench has been eroded, would reach the top of the limestone wall. Below are remnants of a second bench 100 feet above the valley flat. There are other small remnants of No. 1 and No. 2 benches near the north and northwest faces of the mountain wall between Lodgepole and St. Paul's Mission south of Hays. Lodgepole Creek and its tributaries now issue from picturesque box canyons cut in the limestone wall. About half a mile south of the mission the south branch of Peoples Creek issues onto a broad valley flat from Mission Gorge, a picturesque box canyon cut 100 to 300 feet deep through the great wall of limestone. (See pl. 9.) Through this gorge runs the mountain road from Hays to Landusky. About 150 feet above the west side of the flat, on the south branch of Peoples Creek, is a remnant of No. 2 bench, and about 400 feet higher is No. 1 bench. (See pl. 8 *A*.) As shown in Plate 8 *B*, this bench is unbroken to the top of the limestone wall, and its initial slope is practically a continuation of the general profile of the smoothly worn tops of the mountains to the southeast. The smooth and flat but palmately dissected surface of this bench extends far out to the north and northwest until it is finally lost in a maze of sharp branching coulees. About much of the periphery of the mountains, especially on the south and east sides, No. 1

[36] Bowen, C. F., The Cleveland coal field, Blaine County, Mont.: U. S. Geol. Survey Bull. 541, pl. 20, 1914.

bench is mostly destroyed. One remnant at 3,750 to 3,950 feet above sea level, on the west side of Bear Creek Gulch, stands 450 feet above the creek, and the road from Zortman to Malta crosses No. 2 bench several hundred feet lower on the west and traverses a gap due to erosion at the north end of No. 1 bench. (See pl. 7 *C*.)

Remnants of No. 1 bench several miles southwest of the Little Rocky Mountains are the Joslyn Bench, at 3,672 to 3,750 feet (barometric), west of Sipary Ann Butte, in secs. 3, 4, and 5, T. 24 N., R. 23 E., and a smaller remnant about a mile farther north. Beneath the thin loamy soil on the Joslyn Bench is coarse angular to little worn gravel from the mountains. Some of the stones are 1 foot in length. A landslide near the west end of the steep north slope below the bench exposes, beneath the gravel, 10 to 15 feet of buff clay with some gravel intermixed. No trace of fossils was seen on this or any other benches around the Little Rocky Mountains. This is about 21 miles directly east of the extensive remnant of No. 1 bench mapped by Reeves south of the Bearpaw Mountains.

North of the Joslyn Bench are very extensive tracts of No. 2 bench, which slope sharply from the mountain wall.

FLAXVILLE PLAIN IN VALLEY, DANIELS, AND ROOSEVELT COUNTIES

For nearly 80 miles east of the Fort Belknap Indian Reservation no traces of the No. 1 set of benches remain north of the Missouri River. The previous bowing up of the Cretaceous and the Tertiary formations in the Bowdoin dome [37] so facilitated late Tertiary and early Pleistocene erosion that the land surface has been cut well below the level of the Flaxville Plain (No. 1 bench) to the west and east. Even the tops of the Larb Hills, southwest of Glasgow, in southeastern Phillips County and southwestern Valley County, which rise to a maximum altitude of 3,100 feet, or 800 to 900 feet above the level of the Milk and Missouri Rivers to the north and south, respectively, probably do not rise much above what was the level of this valley plain on the west and north.

East of Porcupine Creek the present surface of the land rises higher, and in the eastern half of Valley County and in Daniels and Roosevelt Counties, an area which is about 60 miles wide from east to west and largely underlain by the sandstone and shale of the Lance and Fort Union formations, there are large interstream tracts of nearly flat upland, representing the Flaxville Plain. (See pl. 10 *A*.) Over an area of nearly 1,800 square miles the loamy soil and thin glacial drift on this plain are underlain by deposits similar to those on the Cypress Hills, consisting of coarse gravel, sand, marly clay, and in a few places about 15 feet of volcanic ash. The most conspicuous material is the gravel, which is in many places cemented by calcium carbonate to conglomerate, so that ledges project from eroded slopes. The pebbles, which are exposed in every gully and erosion slope, range from a fraction of an inch to 10 inches in longest diameter. They consist principally of brownish, reddish, and greenish quartzite and argillite, evidently derived originally from the Rocky Mountains, over 300 miles to the west. The pebbles have smoothly rounded or even polished surfaces, and many of them show percussion marks. There is also cross-bedded sand cemented to hard sandstone. (See pl. 10 *B* and *C*.) The Flaxville gravel ranges from a few feet to 100 feet in thickness and rests on the eroded surfaces of the Bearpaw, Lance, and Fort Union formations. The following details are given by Collier and Thom: [38]

In the railway cuts west of Flaxville, where the best collection of fossils was made, about half the material exposed is gravel and the remainder clay and sand; about 1 foot of marl or concretionary calcite is also present. The bedding is very irregular, as might be expected of deposits on the flood plain of a river. North of Flaxville the road to Whitetail crosses a considerable thickness of gravel. Ten miles southeast of Flaxville, in the escarpment at the edge of a plateau, the formation consists of about 35 feet of cemented sand and gravel overlain by uncemented sand. Northeast of Scobey about 55 feet of more or less cemented sand and gravel is overlain by 25 feet of uncemented gravel and soil. * * * The following section of a well southwest of Scobey was given by Martin Presnell, the owner:

Section of a well southwest of Scobey, Mont., in sec. 33, T. 35 N., R. 47 E.

	Ft.	in.
Gravel	6	
Clay	52	
Lignite slack		6
Clay	2	
Lignite slack	1	
Gravel and bones; water.		
	61	6

In a well 2 miles southwest of the Presnell well 28 feet of coarse gravel, carrying bones, was found. About 20 miles west of Scobey there are several good exposures of the lower 20 feet of the formation, together with the underlying Fort Union. The gravel is uncemented and interstratified with cemented sand, and the surface is strewn with loose gravel containing bone fragments. A very striking exposure of the formation occurs 5 miles west of West Fork post office, south of Hell Coulee, in sec. 30, T. 34 N., R. 44 E., where about 30 feet of hard sandstone showing very marked cross-bedding caps the edge of the plateau. * * * The sandstone probably rests on gravel, for an exposure of uncemented gravel was found near the bottom of the coulee. In secs. 19, 20, and 29, T. 35 N., R. 43 E., 8 miles northeast of Avondale, south of Dawson

[37] Collier, A. J., The Bowdoin dome, Mont., a possible reservoir of oil or gas: U. S. Geol. Survey Bull. 661, pp. 205–207, 1918; Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120, pp. 37–39, 1919.

[38] Collier, A. J., and Thom, W. T., jr., op. cit., pp. 181–182.

Coulee, a slightly different phase is presented, as shown by the following generalized section:

Generalized section of Flaxville gravel in secs. 19, 20, and 29, T. 35 N., R. 43 E.

[Thicknesses approximate]

	Feet
Marl, containing a few scattered quartzite pebbles	15
Sandstone cemented with calcite	30
Volcanic ash, white to yellow, very pure but mixed with the underlying gravel at the base	15
Gravel, more or less cemented	20
Fort Union formation.	
	80

The marl (an impure soft white limestone) was either deposited by water flowing over the surface into a shallow pond or gathered from the underlying beds and brought to its present position by percolating waters. Similar occurrences are indicated by fragments of marl in the soil of the townships to the west and north. This is the only locality where pure volcanic ash has been recognized, though similar material mixed with sand has been noted about 12 miles to the northeast. The gravel is very coarse, and well-rounded pebbles at least a foot in diameter, which must have been derived from it, were noted on the surface a short distance away in Dawson Coulee.

The Flaxville Plain, of which these dissevered upland tracts are parts, declines gradually southeastward from an altitude of 3,250 feet west of Opheim to 2,780 feet near Flaxville and 2,620 feet in the northeastern part of T. 31 N., R. 51 E., about 30 miles north of Poplar. This is the most southeasterly point on which the Flaxville gravel is preserved in place north of the Missouri River.

Corresponding with the Miocene or Pliocene plain north of Harlem, in northeastern Blaine County, the several tracts comprising the Flaxville Plain in Valley, Daniels, and Roosevelt Counties are not perfectly flat but are traversed by low, broad ridges trending northwest like worn-down remnants of spurs of a main divide along the Cypress Hills and Wood Mountain upland. They form the present secondary divides, as well as those of Miocene or Pliocene time. In places the retreating front of the last continental ice sheet appears later to have lain along these low ridges and to have left thereon some terminal-moraine deposits. The ridges are probably not wholly morainal, however. Such a ridge extends southeastward past Avondale from a point a few miles south of Opheim. Another is on the upland 10 to 12 miles southwest of Scobey. One tract of high-level gravel southeast of Wood Mountain post office, in T. 3 N., R. 3 W., in southern Saskatchewan, 25 to 30 miles north of Opheim, stands about 3,400 feet above the sea. Over much of the Flaxville Plain glacial drift is very thin on the gravel. In many places scarcely any erratic granite pebbles or boulders are seen. In other places, especially in tracts cut below the original level of the Flaxville Plain, boulders are plentiful and there is 30 to 40 feet of glacial till.

There are no remnants of the Flaxville Plain north of the Missouri River, either close to or east of the Big Muddy Valley. It is possible that the highest parts of the Coteau du Missouri in northwestern Williams County, N. Dak., rise nearly to this horizon.

There is ground for the belief that the Missouri River of Miocene or Pliocene time flowed northeastward across Roosevelt County and southeastern Sheridan County and that this was the beginning of the abandoned valley (deepened later) which extends northeastward from a point 5 miles east of Poplar, as shown on the Poplar, Brockton, and Homestead topographic maps. The stream at this stage probably flowed in a channel that would now be about 2,500 or 2,600 feet above sea level in the vicinity of Poplar, had it not long since been lowered—that is, it was at a level 500 or 600 feet higher than the present stream. The gradient of the present valley bottom from Harlem (altitude 2,350 feet) to Poplar (1,950 feet) is 400 feet in about 180 miles, or about 2.2 feet to the mile. The supposed altitude of the late Tertiary valley bottom at Harlem was about 3,000 feet, and a grade equal to that of the present valley bottom would reach 2,600 feet near Poplar, making no allowance for any subsequent differential uplift increasing to the west. Approximately the same altitude is found by projecting the gradient of the Flaxville Plain southeastward to the high gravel benches bordering the Yellowstone River in the Glendive quadrangle. As indicated below (p. 30), these bench remnants are correlated with the Flaxville Plain.

TERRACES OF JUDITH RIVER BASIN

The Judith River Basin, which drains northward to the Missouri River, is inclosed by several more or less isolated groups of mountains—the North and South Moccasin Mountains and Judith Mountains on the east, the Big Snowy Mountains on the southeast, the Little Belt Mountains on the southwest, and the Highwood Mountains on the west.

The floor of the basin rises from a general altitude of about 3,000 feet, on the brink of the Missouri River gorge, to 4,500 to 5,000 feet at the foot of the neighboring abrupt mountain slopes. This floor consists in general, in the interstream areas, of extensive tracts of smooth, nearly flat, gently sloping benches, on which the loamy soil is underlain by coarse alluvial gravel. The Judith River and its tributaries have cut deeply into the smooth bottom of the basin, so that the benches are dissevered by branching canyons and steep-sided coulees 100 to 600 feet or more in depth.

These benches comprise remnants of two or three distinct sets of great coalescing alluvial fans, similar to those bordering the front range of the Rocky Mountains in and north of the Sun River Basin. The inference that the several sets of benches in these two regions were formed contemporaneously seems justified from a study of their topographic and physiographic relations. In the Judith River Basin what appear to be the No. 2 benches are the best preserved. Of the No. 1 bench only small remnants have survived subsequent erosion. Planation at the third level had developed valley bottoms 1 mile to several miles in width, when it was interrupted by the canyon-cutting cycle that is still in progress. Contour maps by Calvert[39] and Fisher[40] show the benches in the upper (southern) half of the Judith River Basin but do not differentiate the several sets. Representatives of No. 1 bench are the flat tops of the Stanford Buttes at 4,600 feet, 3 miles west of the village of Stanford. These tops are 100 to 200 feet above No. 2 bench on the west and 300 feet above No. 3 bench, on which stands the village to the east. The buttes are capped with 25 to 30 feet of conglomerate composed mostly of pebbles of limestone and volcanic rocks, with some quartzite and sandstone, ranging from a fraction of an inch to 1 foot or more in length (mostly 2 to 6 inches) and cemented together by calcium carbonate. This is the Stanford conglomerate of Weed.[41] The pebbles are subangular to fairly well rounded and appear to be stream-transported material from the Little Belt Mountains, 5 or 6 miles to the south.

The highest of the bench remnants east of Stanford appear to belong to the No. 1 bench which headed in the Little Belt Mountains. One tract 5 to 6 miles north of Windham is at about 4,500 feet above sea level. The village of Benchland (4,324 feet) stands on No. 2 bench below a bluff that rises to the eroded south end of a table-land. Large blocks of conglomerate near the Great Northern Railway have slid down from the cap of No. 1 bench above the bluff. What appears to be the same bench was crossed by the writer southeast of Denton, near Hoosac Tunnel on the Chicago, Milwaukee, St. Paul & Pacific Railway. At this place the gravel top is 3,800 to 3,900 feet above sea level.

This bench is here 300 to 400 feet above a lower (No. 2) bench into which the Judith River has cut a gorge 150 feet deep. East of the river are benches heading in the Moccasin Mountains. One of these sloping benches high up on the west flank of the South Moccasin Mountains, which was examined by the writer, rises nearly 250 feet in less than a mile and joins the mountain slope at a notch cut in the beveled edges of the upturned Jurassic formations (pl. 11 *A*), at about 4,700 feet above sea level, or about 1,100 feet above Warm Spring Creek, 2 miles north and 1,100 feet below the crest of the mountains. It is really a torrential fan composed of angular to subangular fragments, largely of limestone and porphyry, ranging in size from those measuring only a fraction of an inch to blocks 4 feet long.

The travertine deposit forming The Park, a large bench mapped by Calvert[42] on the south slope of the North Moccasin Mountains, appears to have been formed on an erosion slope at about the same geologic horizon (4,000 to 4,600 feet above sea level) and perhaps at the same time as the No. 1 gravel bench. With these are probably to be correlated a similar travertine deposit which Calvert found capping Flat Mountain, at the south end of the Judith Mountains, 9 miles east of Lewistown, and perhaps also the highest of the gravel benches east of the Judith Mountains. The connection of the latter gravel benches with the mountain slope has been destroyed by erosion. A high gravel bench at the south end of the McDonald Creek divide, where it lies on the flank of the Little Snowy Mountains, is 5,100 to 5,200 feet above sea level. A long, narrow remnant of No. 1 bench on the west side of Cottonwood Creek, west of Lewistown, rises southward to 4,600 feet some distance from the slope of the Big Snowy Mountains, where it is cut away. Remnants near Judith Gap rise to 5,000 feet at the west end of the Big Snowy Mountains, and to the same level in places bordering the Little Belt Mountains. One of these, south of Utica, is 600 feet above the Judith River.

There are finely developed benches about the west, north, and east margins of the North Moccasin Mountains and all around the Judith Mountains. Northeast of Deerfield, which is on No. 3 bench at an altitude of 3,600 feet, and above a bluff of Eagle sandstone, is an extensive remnant of No. 1 bench which rises eastward from about 4,100 feet (barometric) to a higher level on the flank of the North Moccasin Mountains. This is probably 700 to 1,000 feet above the Judith River a few miles to the west.

West of Armells the graded road traverses No. 1 bench for several miles between Armells and Deer Creek. This bench heads in the reentrant north of Judith Peak at about 4,600 feet above sea level. In August, 1921, a cut on the newly graded road at the west margin of this bench, about 2 miles from the mountain slope, exposed 15 feet of very coarse, angular, little-worn alluvial material derived from the mountains to the south. Most of the stones were less than 6 inches long, but many were 1 foot or more and some 3 to 4 feet. The slope of the flat surface of the bench is about 100 feet to the mile at this place. What appears to be another remnant of No. 1 bench extends from the vicinity of Roy southwest toward

[39] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, pp. 41–43, pl. 1, 1909.

[40] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, pl. 1, 1909.

[41] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), p. 2, 1899.

[42] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, pp. 35–40, 1909.

Cone Butte. North of the Roy branch of the Chicago, Milwaukee, St. Paul & Pacific Railway most of the benches have been cut away by erosion of streams draining to the Missouri and Musselshell Rivers.

Extensive tracts of flat bench land east of the Judith Mountains in T. 16 N., R. 21 E., rise to about 4,500 feet above sea level within 2 to 3 miles of the mountain front. An eastward slope of less than 30 feet to the mile would connect these tracts with the terrace on the Musselshell River west of Mosby. They may, however, represent No. 2 bench. As at the Little Rocky Mountains, so here, the highest of these benches was probably graded to the smoothly worn upper slope of the mountains above the abrupt marginal wall of upturned limestone. Subsequent erosion cut the sharp, narrow gorges like Maiden Canyon. (See pl. 12 *A*.)

TERRACES OF MUSSELSHELL VALLEY

In the Musselshell Valley west of Roundup there are remarkably preserved benches, evidently the dissevered remnants of vast coalescent alluvial gravel fans, heading at the slopes of the adjacent mountains. On the southwest are the Crazy Mountains, on the west the Castle Mountains, on the northwest the Little Belt Mountains, and on the north the Big Snowy Mountains. Much of the basin has been mapped by Bowen, Woolsey, and Stone, and the gravel benches are shown on a structure map by Bowen[48] and are described as follows:

Terrace gravels, consisting chiefly of waterworn pebbles of limestone, chert, sandstone, and igneous rock of several types, in places well consolidated by calcareous cements into a true conglomerate, are widespread in this area. The gravel occurs at two or more levels, but the most prominent deposits are at the top of the highest buttes and ridges. These detached areas rise to about the same elevation, so that if the surface represented by them were restored it would form a plain rising gradually toward the mountains. The thickness of the gravel ranges from a few feet far out on the plain to at least 80 feet nearer the mountains, where wells have penetrated it to that depth. Below these highest terraces there is at least one other level at which the gravel occurs. No especial study was made of the relation of these two terrace levels, so that it is not known whether those at the lower level represent a reworking and redistribution of those at the higher level or whether they are simply residual products that have settled to their present position during the process of erosion. The age of the gravels has not been determined. Those at the higher level truncate all formations from the Fort Union (exposed in adjoining areas) to the Kootenai. They are therefore younger than the Fort Union and are probably to be correlated with the Flaxville gravel of Miocene or early Pliocene age, north of Missouri River, described by Collier and Thom. It is possible, however, that they correspond to the Oligocene gravels of White River age occurring in the Cypress Hills of Canada, described by McConnell and Cope.

The present writer does not think it probable that any of these gravel deposits are as old as Oligocene.

In 1911 Calvert studied the geology of the Big Snowy Mountains, and in an unpublished manuscript he describes the terrace gravel bordering these mountains on the south as follows:

In the area south of the Big Snowy Mountains terrace gravel covers much of the interstream divides, extending in places high up on the mountain flanks and effectually concealing the underlying rocks. The gravel is composed almost entirely of cemented limestone pebbles derived from the Madison, though occasional fragments of strata higher in the section are present. They are believed to have been formed as coalescing alluvial fans at a time when the general stream levels were much higher than at present and when precipitation was much greater than now. No evidences of ice action were observed in the Big Snowy Mountains, so that the gravel is not considered to be of glacial origin, but the formation of the gravel terraces was probably attendant upon some one or more of the glacial epochs.

No attempt was made in the field to outline the areas occupied by terrace gravel, though a large portion of the district immediately south of the Big Snowies is covered by this material.

In 1921 the present writer made a hasty reconnaissance of these gravel benches in an attempt to correlate the different sets with those of the Missouri and Yellowstone Rivers and their tributaries. In 1920 Frank Reeves mapped the gravel benches north of Roundup in Ts. 9, 10, and 11 N., Rs. 24 and 25 E., and to him the writer is indebted for unpublished data. These have not been mapped quite up to the east end of the Big Snowy Mountain uplift, where they head, but a few miles out they reach altitudes of 4,050 feet or more. From these heights part of the benches decline eastward 400 feet in 10 miles, or 40 feet to the mile, and others slope southeastward about 400 feet in 16 miles, or 25 feet to the mile. It is thought that these remnants mapped by Reeves probably belong to the No. 2 bench, as do also the most of the more extensive tracts mapped by Bowen westward to the Little Belt, Castle, and Crazy Mountains about the head of the Musselshell Valley. There are, however, scattered throughout the basin west of Roundup numerous dissevered and isolated higher remnants probably representing No. 1 bench. These generally stand 100 feet or more above the adjacent tracts of No. 2 bench and clearly represent an earlier stage of mountain denudation and of alluvial erosion and deposition on the plains. The fact that all benches bevel smoothly across edges of the Mesozoic and Tertiary shales and sandstones, wherever they are upturned, indicates that they represent two long-continued stages of baseleveling on the plains separated by an interval of general downcutting by the streams induced by increased gradients.

Several remnants of No. 1 bench were crossed by the writer on a road running westward from the east end of the Big Snowy Mountains past Bercail post

[48] Bowen, C. F., Anticlines in a part of the Musselshell Valley, Musselshell, Meagher, and Sweet Grass Counties, Mont.: U. S. Geol. Survey Bull. 691, pl. 25, p. 190, 1918. See also U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 56), 1899.

office, in T. 10 N., and thence to Judith Gap. From altitudes of 4,800 to 5,000 feet near the mountain front these smooth flat benches slope rapidly southeastward toward the Musselshell River. The remnants of No. 1 bench mostly extend but a few miles before they give place to the more extensive No. 2 benches. The occurrence of remnants of the higher bench far to the south, however, indicates that No. 1 bench was probably continuous over the whole area north of the river before the lower benches were developed. One of these remnants is traversed by the main graded road between Hedgesville and Harlowton. This is 400 to 450 feet above the Musselshell River, 3 to 4 miles to the south. The higher remnants near the mountains are separated by strips of the second set of terraces bordering the streams, and these in turn are trenched by rather broad flat-bottomed inner valleys. Most of the remnants of No. 1 bench range from a few rods to a mile or two in width, though some are several miles wide; and they stand 50 to 150 feet or more above the remnants of No. 2 bench. The 200-foot contour interval used on the Big Snowy Mountain and Little Belt Mountains topographic maps is too large and the horizontal scale too small to differentiate clearly the sets of bench remnants from each other and from intervening, gently undulating areas where the flat, gravel-capped tops have been worn away by erosion.

The thin pebbly soil, which is cultivated on all these benches, is underlain by coarse waterworn gravel. The gravel ranges in size generally from fine pebbles to 8-inch cobblestones, but some stones are about a foot in longest diameter. South of the Big Snowy Mountains and of the eastern part of the Little Belt Mountains the pebbles are mostly of limestone. West of R. 13 E. purplish and red quartzites are more noticeably intermingled.

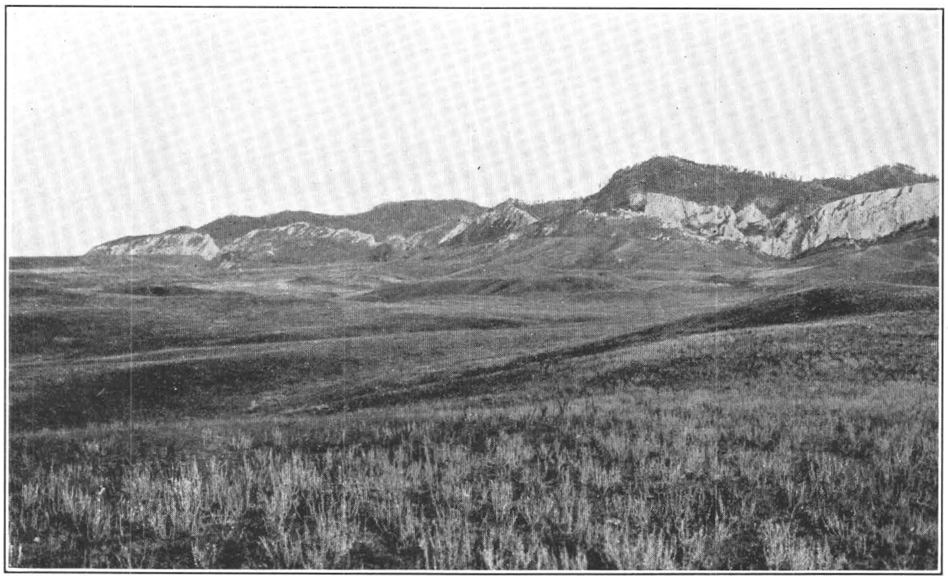
It is possible that the original connection of the highest benches with the mountain slope may have been at a position now as high as 6,000 feet above sea level. This was certainly the case west of Judith Gap, where No. 1 bench formerly overtopped the foothill strike ridges of upturned Quadrant and Ellis formations at the southeast front of the Little Belt Mountains. Considerable tracts of smooth, flat No. 1 bench land under cultivation are traversed by roads north and northwest of Harlowton and east of Haymakers Creek at altitudes ranging from 4,500 feet near Harlowton to more than 5,500 feet a few miles from the mountains. The truncated heads of these benches stand to the south of and high above the road that leads west from Judith Gap to the forest ranger station on Hopleys Hole Creek.

No remnants of No. 1 bench were noted about the flanks of the Castle Mountains between the Musselshell River and its South Fork, though, as stated below (p. 40), there is a possibility that the high bench between Alabaugh and Warm Spring Creeks 5 miles west of Lennep, which is covered with drift of a mountain glacier, may represent No. 1. This bench is 5,800 to 6,000 feet above sea level, or at about the same altitude as the slopes north and south of the pass at Loweth station. Alabaugh Creek has cut its narrow valley 300 to 400 feet below the top of this bench.

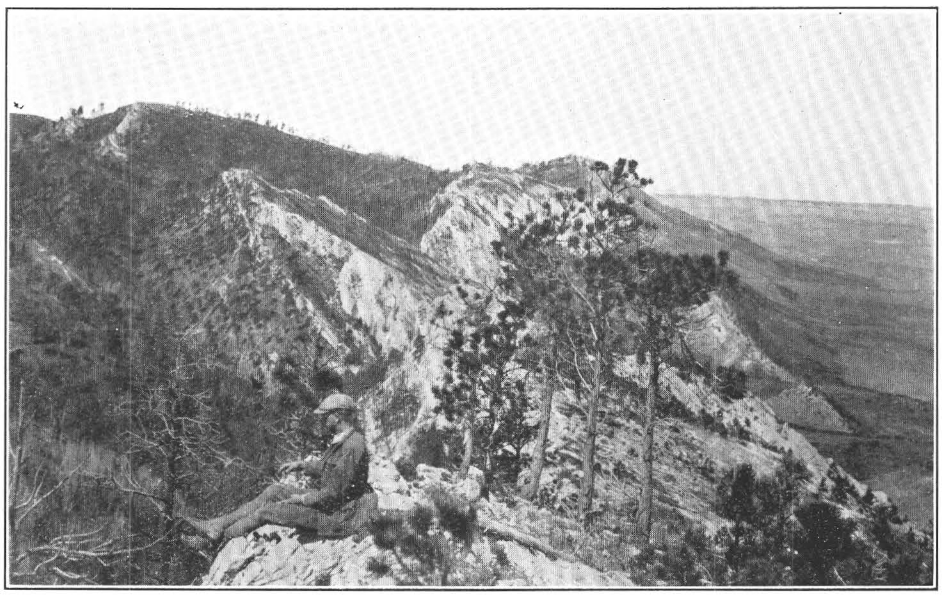
The relations of most of the bench or terrace remnants south of the Musselshell River in southern Wheatland County and southeastern Meagher County have not been studied by the writer. South of Harlowton the road to Melville crosses broad tracts of No. 2 bench bordering Lebo Creek and American Fork and at 13 to 14 miles runs through a notch in a narrow remnant of No. 1 bench at 5,000 feet above sea level. This bench, which is in northern Sweet Grass County, appears to be continuous southwestward to a point north of the west side of Porcupine Butte, beyond which it is cut away. At this place the bench is 400 feet or more above the streams on the north and south. It originally headed at the east base of the Crazy Mountains, at an altitude of probably more than 6,000 feet.

The question arises at this point, Did No. 1 bench overtop the divide and extend southward without a break to the Yellowstone Basin, or was there even at this early stage a dividing ridge between the two basins higher than No. 1 bench and extending eastward from Porcupine Butte and the Cayuse Hills to and beyond the Bull Mountains, southeast of Roundup? As bearing on this question the following relations may be cited:

To the south of the divide the nearest remnant of No. 1 bench examined by the writer about 8 miles south of Porcupine Butte, is at about the same altitude as the one north of the divide (5,800+ feet). It thus appears that this level is sufficiently high to have been continuous across the divide near the east base of Porcupine Butte. The strip of country to the east is much dissected, and, so far as known to the writer, there are no remnants of the high benches in this area. The sandstone on the crest, 7 to 10 miles north of the village of Rapelje, is 4,600 to 4,800 feet above sea level, and 20 miles or more west of the Bull Mountains the divide is mostly above 4,000 feet. Eldridge Mesa, in the Bull Mountains, stands at about 4,700 feet. The writer found no bench gravel on the nearly flat top of this mesa in secs. 27 and 28, T. 6 N., R. 27 E. Due south of the Bull Mountains the flat-topped crest of the divide between the Yellowstone River and Pryor Creek, 7 to 8 miles east of Billings, is capped with bench gravel at 4,000 feet, or 900 to 1,000 feet above the river a few miles away. This may, however, be older than the No. 1 benches. Comparison of these altitudes with those of the other high remnants of benches south



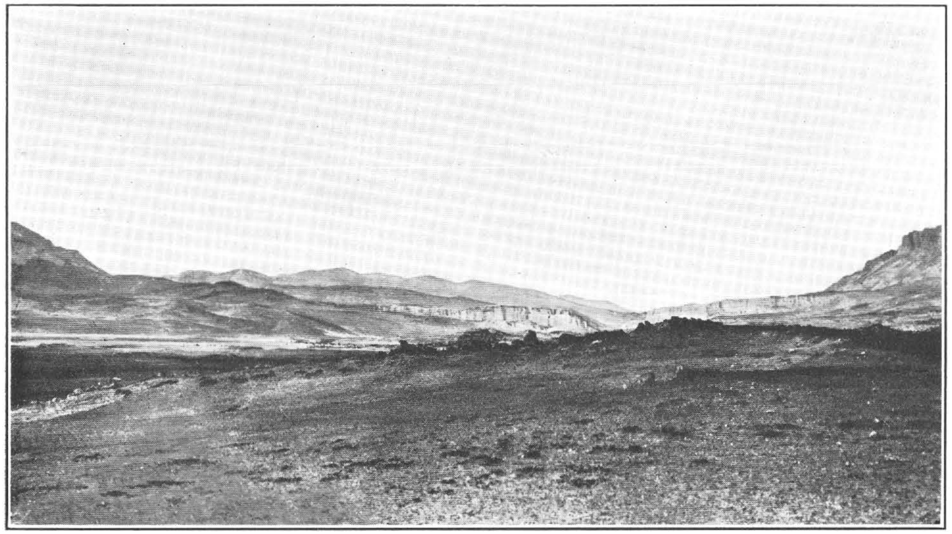
A



B

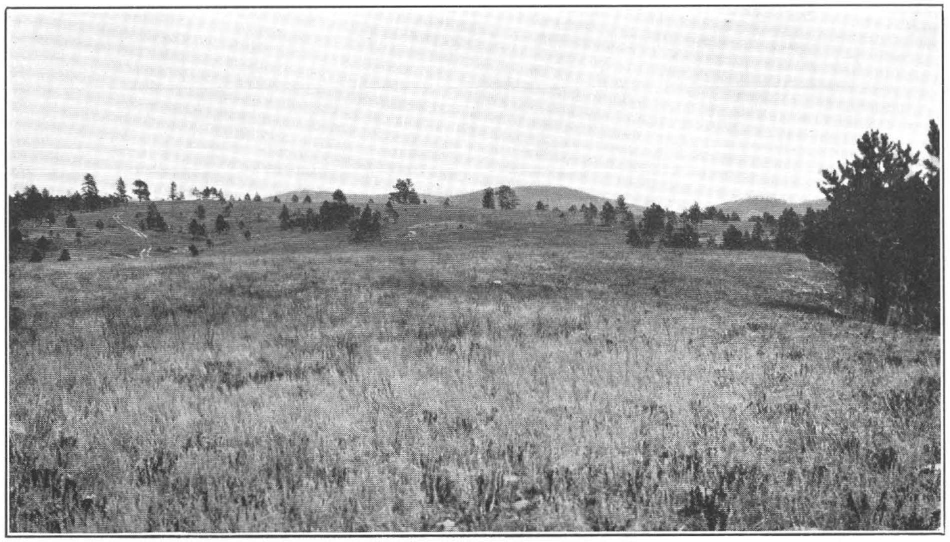
LITTLE ROCKY MOUNTAINS, MONT.

A. North front of mountains east of Hays post office, showing great wall of upturned Paleozoic limestone. The horizon of top of wall is correlative with Flaxville Plain (No. 1 bench). Remnant of No. 2 bench at left. *B*. View looking west along the notched top of the great north wall of limestone, 600 to 700 feet above the plains at right.



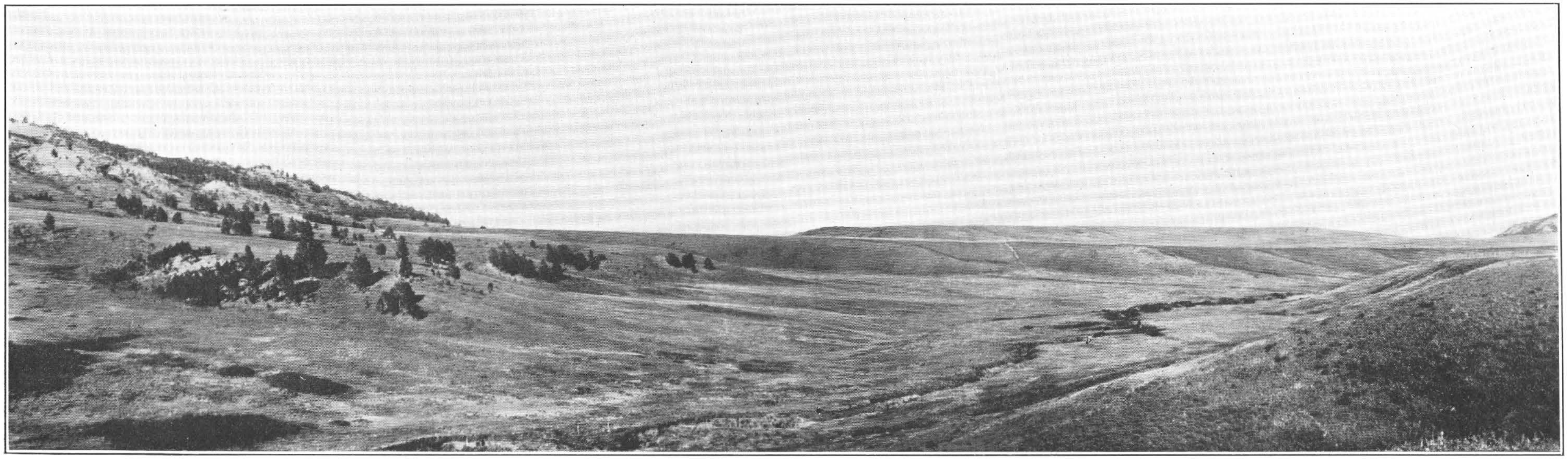
A. SUN RIVER, MONT., AT MOUTH OF CANYON

Showing cross profile of ancient Pliocene or Pleistocene high-level valley 4 miles wide above the top of the 1,000-foot lower wall of limestone.



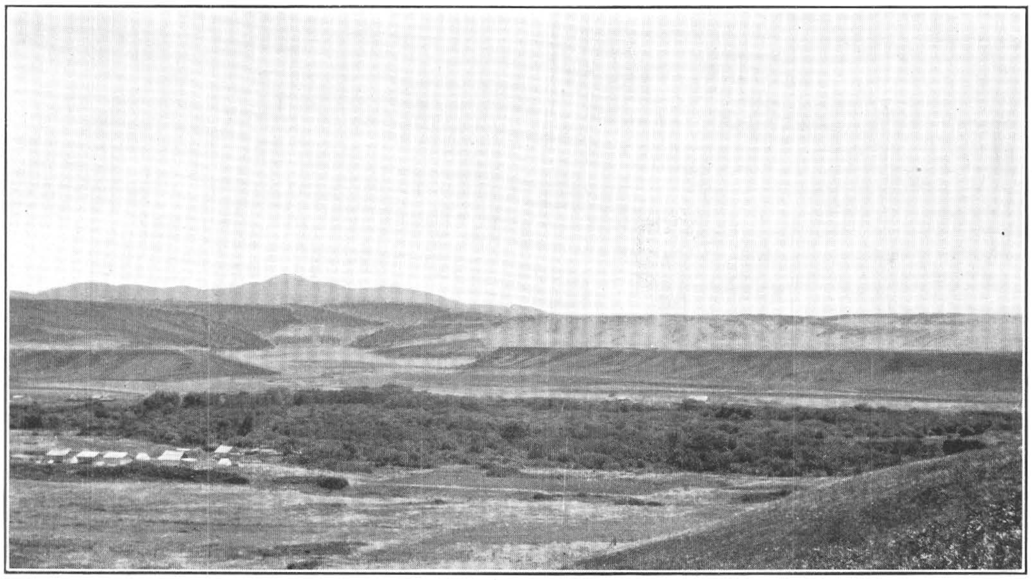
B. WORN TOP OF THE LITTLE ROCKY MOUNTAINS, MONT.

Looking east across the beveled top of the limestone wall from a remnant of the Flaxville Plain, or No. 1 bench, north of St. Paul's Mission.



C. VIEW SOUTHEAST OF ZORTMAN, MONT.

Showing remnants of the Flaxville Plain, or No. 1 bench (upper), and No. 2 bench (middle). South wall of mountains at left.



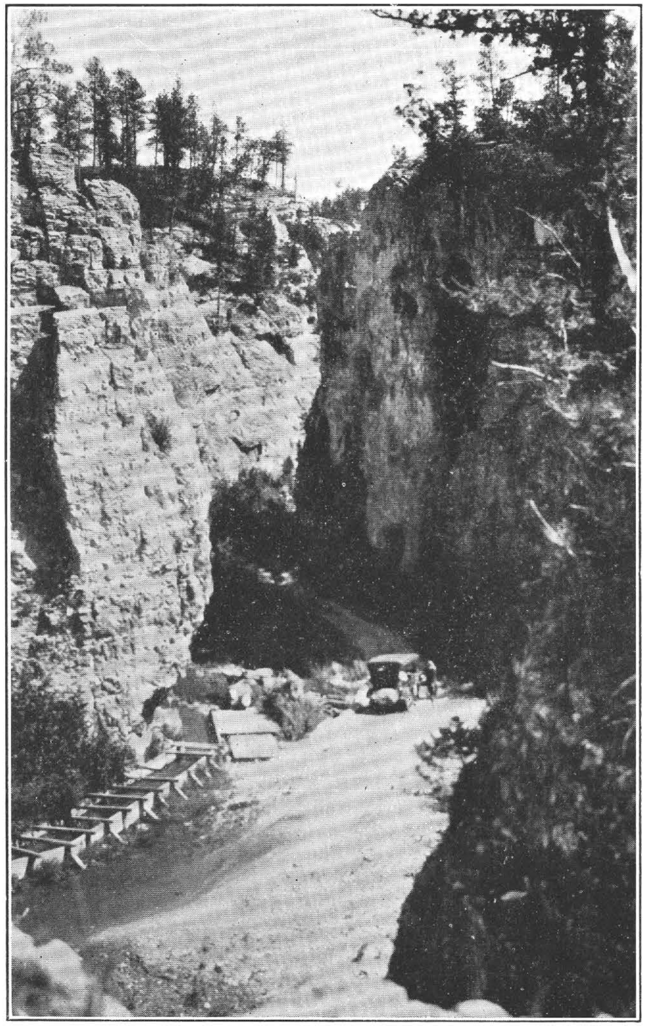
A. NEAR ST. PAUL'S MISSION

View across Peoples Creek (altitude 3,550 to 3,650 feet), showing No. 1 bench (3,950 to 4,300 feet) and No. 2 bench (3,700 to 3,800 feet), sloping northward from the mountains at the left.

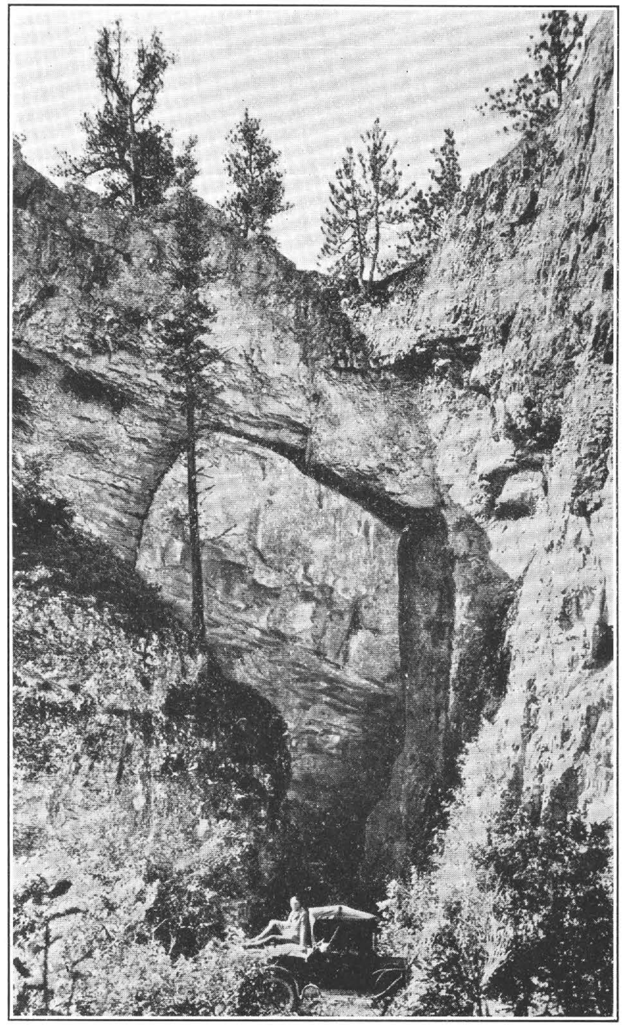
B. FLAXVILLE PLAIN, OR No. 1 BENCH, WEST OF ST. PAUL'S MISSION

Graded to the top of the limestone wall and the general profile of the mountains at the left.

LITTLE ROCKY MOUNTAINS, MONT.

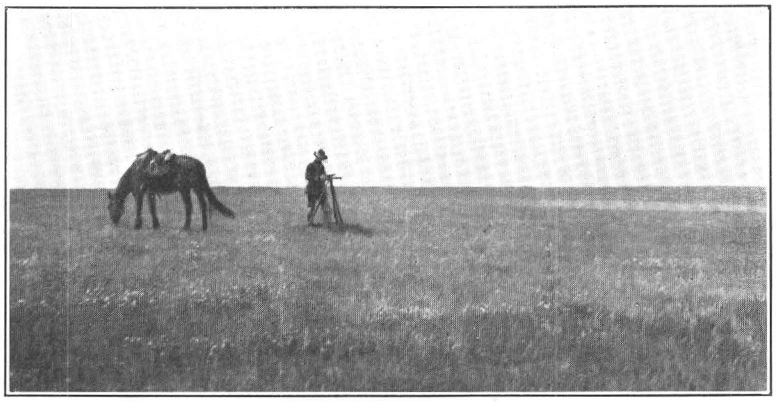


A. MISSION GORGE, SOUTH OF ST. PAUL'S
Cut through the great limestone wall by Peoples Creek.

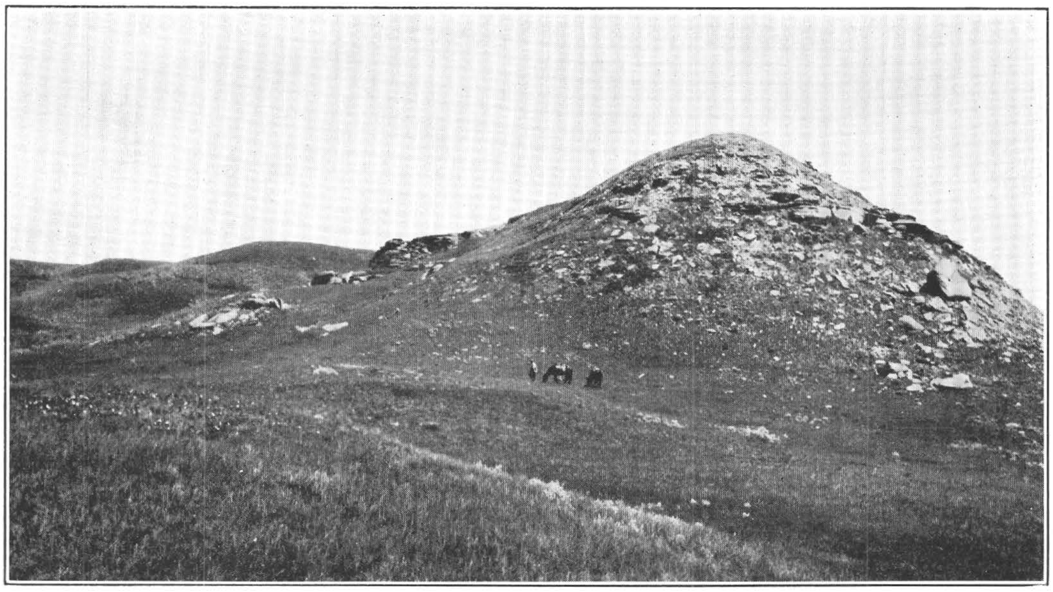


B. NATURAL BRIDGE, WEST SIDE OF MISSION GORGE

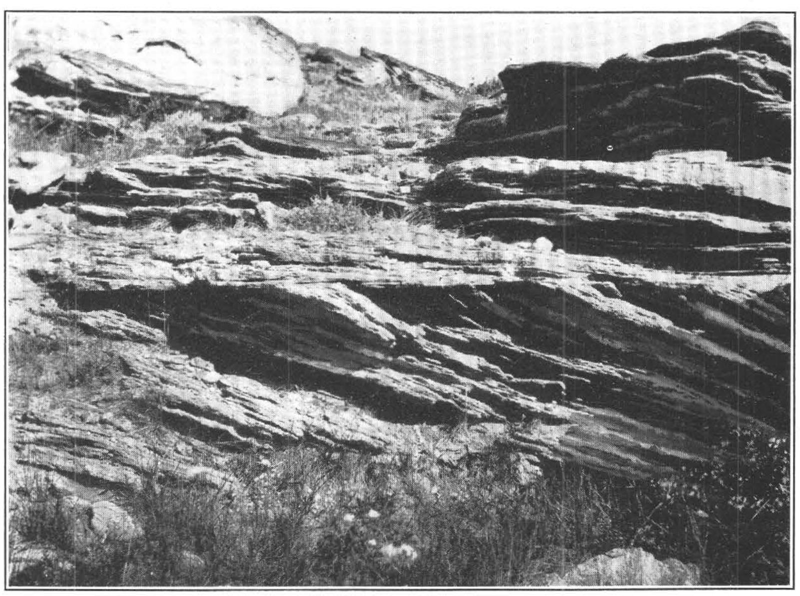
LITTLE ROCKY MOUNTAINS, MONT.



A. FLAXVILLE PLATEAU 15 TO 20 MILES WEST OF SCOBEY, MONT.



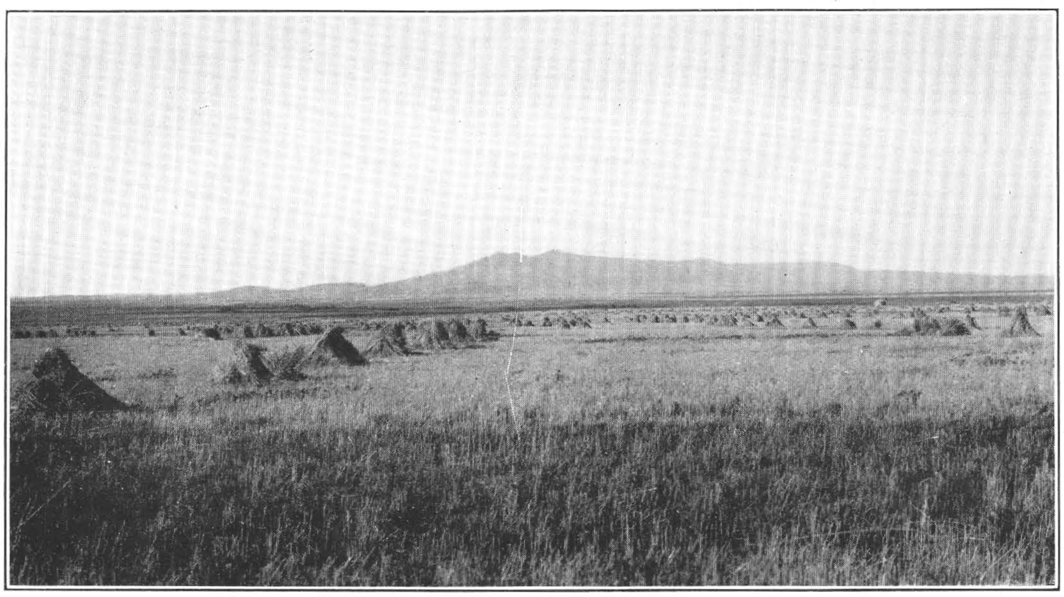
B. OUTCROP OF CEMENTED FLAXVILLE GRAVEL IN ESCARPMENT OF PLATEAU, 6 MILES NORTHWEST OF OPHEIM, MONT.



C. CROSS-BEDDING OF FLAXVILLE GRAVEL 18 MILES SOUTHWEST OF SCOBEY, MONT.

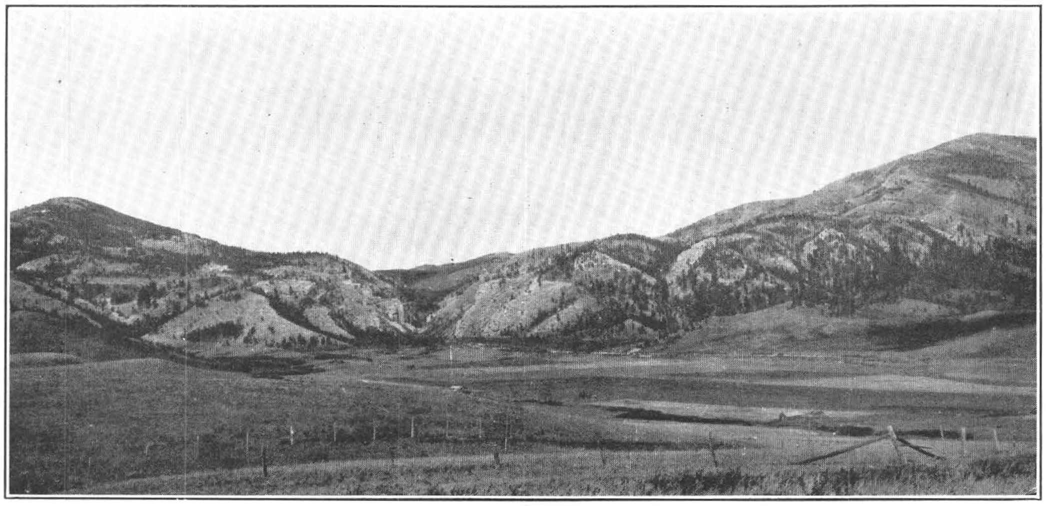
All photographs by A. J. Collier.

A. REMNANT OF HIGHEST (No. 1) GRAVEL-CAPPED BENCH (IN FOREGROUND) ON WEST FLANK OF MOUNTAINS

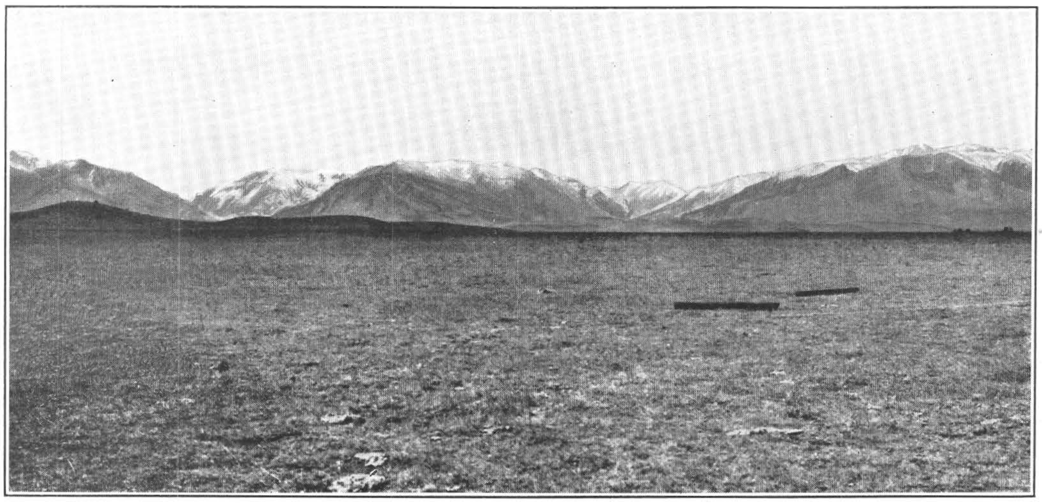


B. VIEW NORTH ACROSS THE GRAVELLY No. 2 BENCH SOUTHWEST OF LEWISTOWN

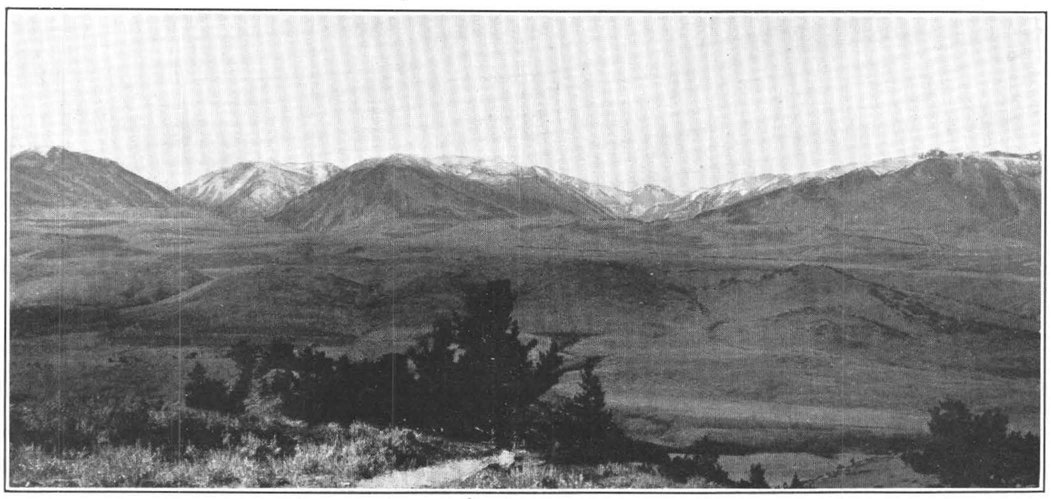
SOUTH MOCCASIN MOUNTAINS, MONT.



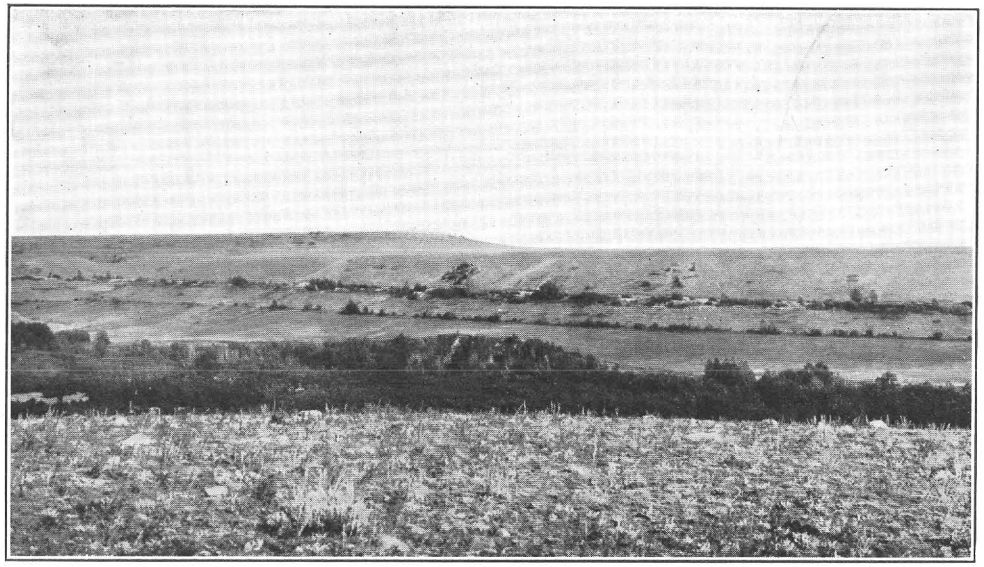
A. SMOOTHLY WORN TOP AND EAST FRONT OF JUDITH MOUNTAINS, MONT.
Mouth of Maiden Canyon in middle ground.



B. VIEW EAST OF ROSCOE, MONT.
Showing smooth flat top of the highest (Flaxville or No. 1) gravelly bench. Beartooth Mountains in background.

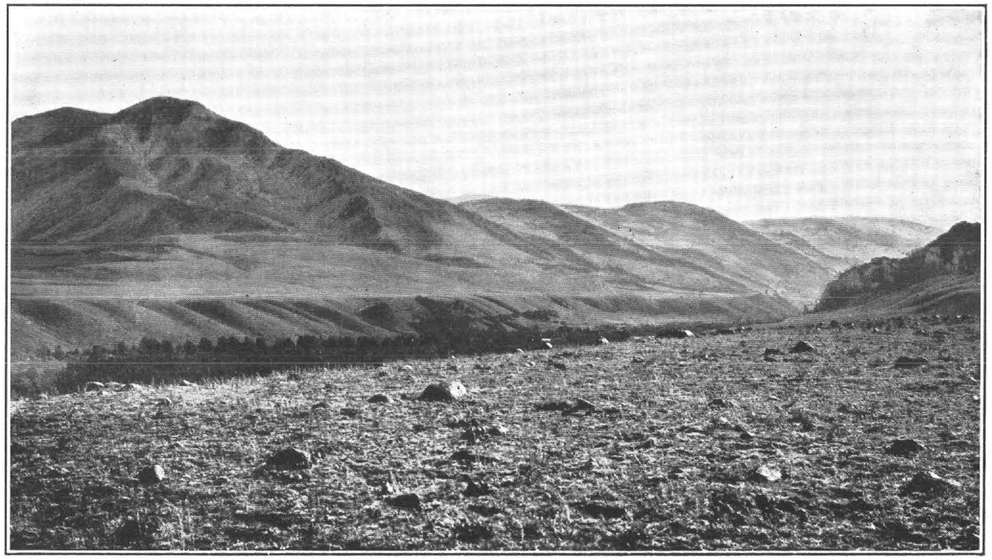


C. DISSECTED No. 2 BENCH SOUTH OF ROSCOE, MONT.
Heading at Beartooth Mountains, in background.



A. HIGHEST (No. 1) BENCH AND MIDDLE (No. 2) BENCH EAST OF ROCK CREEK, NEAR RED LODGE, MONT.

Two irrigation ditches run northward (to left) along the steep slope above the bottom of the valley.



B. No. 2 BENCH (IN FOREGROUND AND MIDDLE GROUND) HEADING IN MOUTH OF ROCK CREEK CANYON (AT RIGHT)

Beartooth Mountains in background.

C. VIEW IN SHOSHONE NATIONAL FOREST, WYO., 12 TO 15 MILES SOUTHWEST OF CLARK POST OFFICE

Looking southward across valley of upper Clark Fork of the Yellowstone River into basins of Sunlight and Dead Indian Creeks. Volcanic peaks of Absaroka Mountains in background. Shows broad Pliocene or Pleistocene valley eroded in Paleozoic rocks and, sharply cut into the bottom of this valley, the narrow branching box canyons of a later (Pleistocene?) cycle of erosion, more than 1,000 feet deep in Archean granite and gneiss. The broad bench, or bottom of the ancient valley, is probably to be correlated with the highest (No. 1) bench on the plains to the east.

of the Yellowstone River seems to indicate that the valleys of the Yellowstone and Musselshell, at the time of the formation of No. 1 bench, were broad, shallow basins distinctly separated by a worn-down divide whose crest was not more than 700 or 800 feet above either of the streams. There are no data in hand showing that the slopes of this broad divide were ever covered with bench gravel east of the vicinity of Melville. Even if in Oligocene time the great reentrant encircled by the mountains from the Big Snowy Mountains on the north around the west end to the Pryor and Big Horn Mountains on the south constituted a single drainage basin, it is probable that by early Pliocene time it was definitely divided.

NO. 1 BENCH IN YELLOWSTONE VALLEY

BENCHES ABOVE CUSTER

In the Yellowstone Valley No. 1 bench is well represented, though the location of the remnants and their height above the adjacent streams indicate a very large amount of erosion since the streams were spreading gravel on this ancient plain. A reconnaissance study of these benches was made by the writer in 1921 and 1922, but not all were mapped in detail. Here as elsewhere such detailed mapping as has been done is very largely the work of other geologists.

There are a few remnants of No. 1 bench in the northeastern part of the Livingston quadrangle heading at the southeastern base of the Crazy Mountains. One of these on the north side of Swamp Creek, at an altitude of 6,100 to 6,500 feet (barometric) stands 200 feet or more above the extensive No. 2 bench. The grade of the upper bench projected to the mountain slope, across an interval of a mile or so where it has been cut away, overtops the summit levels of most if not all the adjacent foothills. This bench appears originally to have headed in the gulch south of Crazy Peak. The pebbles, mostly of igneous rock, range in size from a fraction of an inch to 3 feet. As far as noted none of them show evidence of glacial action.

In the Shields River Basin there are several remnants of No. 1 bench heading near the southwest, west, and northwest flanks of the Crazy Mountains. Some of these were examined by the writer in 1922. The Sheep Cliffs and some other hills, which are capped with igneous rock south and west of the mountains, rise above No. 1 bench. At all other places the old surface has been cut away, leaving the present surface at lower levels. The most extensive remnant of No. 1 bench heads at the south foot of the mountains, near the Absaroka National Forest boundary, on the east side of Rock Creek, 7,000 feet or more above sea level. According to the topographic map, it slopes thence southwestward toward Chadbourn, about 1,200 feet in 5 miles, or at a rate of about 240 feet to the mile. These remnants stand hundreds of feet above the beds of the present streams where they emerge from the mountain gorges. If there were benches on the west side of the Shields River with similar grades and altitudes, they would almost, if not quite, overtop the range of hills extending north of Bozeman Pass and reach the Bridger Range near the top. By early Pliocene time, when the No. 1 benches were being formed, the Yellowstone River had probably notched the top of the wall of upturned limestone south of Livingston down to 5,500 feet above sea level where now it flows at about 4,550 feet in the lower canyon, and farther east the stream may have been flowing at a level about 1,000 feet below that of the top of the Sheep Cliffs—that is, at about 5,200 feet.

Extensive remnants of gravel-capped benches are preserved on either side of the lower few miles of the Boulder River south of Big Timber. (See Big Timber topographic map.) This stream is one of the principal tributaries of the Yellowstone River. Heading in the Absaroka Range on the high plateau, north of Yellowstone National Park, the main stream and the West Boulder traverse profound canyons. After being joined by the East and West Boulder the stream continues northward in a beautiful valley cut 300 feet below the bordering No. 2 terrace and 550 to 600 feet below the one remnant of No. 1 bench, which is on the east side of the stream 6 to 8 miles south of the village of Big Timber, at 4,750 to 4,900 feet above sea level. Farther south this bench appears to have been entirely cut away. It is probable that the surface of this bench projected southward with a normal increase in gradient would overtop all the foothills and reach the mountain front 7,000 feet or more above sea level at the beveled top of the great wall of upturned limestone where the narrow V-shaped gateways of the canyons are 1,000 feet or more in depth. The top of the limestone wall is 2,000 feet or more below the East Boulder Plateau, to the south.

From the Boulder River southeast to the Stillwater River no remnants of No. 1 bench are known to be preserved. The benchlike surfaces shown on the southeastern part of the Big Timber topographic map are, in part at least, erosional, corresponding closely to dip slopes on the Lance sandstones. Some of the surfaces are, however, near what must have been the position of No. 1 bench, especially south of Reed Point, where the upland is 800 feet or more above the river. As indicated above, it is unlikely that the ridges north of the Yellowstone and east of Sweetgrass Creek ever were truncated by No. 1 bench.

Most of the gravel-covered bench remnants above the bluffs of the inner valley of the Yellowstone, as far downstream as Columbus, appear to correspond to the second set of terraces. At the mouth of the Stillwater River these remnants are 400 feet above the Yellowstone River.

In southwestern Stillwater County and in Carbon County the bold northeastern front of the Beartooth Mountains is bordered by a zone in which are numerous remnants of No. 2 bench and a few of No. 1. These were mapped by Calvert,[44] and their altitudes were shown by contours. Some of these were examined by the present writer in an effort to discriminate the different sets and correlate them with the benches described above. One of the best-preserved remnants of No. 1 bench heads about 3 miles east of Roscoe and extends thence northeastward more than 5 miles to and beyond the limit of the area mapped by Calvert. The smooth, flat top, which is 400 to 500 feet higher than Butcher Creek, has an altitude of 5,400 feet at the head, or truncated southeast end, and slopes thence northeastward about 50 feet to the mile. (See pl. 12 *B* and *C*.) At the head of the bench, and rising above its flat surface, is a small, smooth, grassy ridge whose composition, owing to lack of exposures, was not ascertained. It is probably composed of wind-blown material lodged in the lee of the crest of the steep eroded margin of the bench. The material underlying the thin top soil of the bench is exposed about the edges of the upland and in the sides of some coulees cut in the flat plain. It is coarse, unsorted gravelly and bouldery granitic material, with no limestone. The stones are partly rounded but largely subangular and mostly range in size from a fraction of an inch to 1 foot. There are many 2 to 3 feet long, some as much as 4 feet, and one boulder 3 by 4 by 6 feet was measured. The lack of sorting and stratification and the large size of many of the boulders, taken in connection with the fact that the head of the bench is about 7 miles from the mountain front, strongly suggest that the material is glacial drift. No striated stones were found, however. The surfaces of most of the stones are etched, and many of the pebbles and boulders are disintegrating as the result of long exposure to weathering. There are few hills in the region as high at that distance from the mountain front. If the sloping surface were projected southwestward to the mountains, with a normal increase in gradient, it would probably overtop all the foothills and reach the mountain front at a height which is now 6,500 to 7,000 feet above sea level.

The gradient of these benches, of course, decreased markedly downstream, but, even allowing for this, it seems improbable that No. 1 bench east of Roscoe would have overtopped all the divide between the Stillwater River and Clark Fork, inasmuch as the crest of the ridge, 9 miles southeast of Columbus, rises to 4,955 feet in the southeastern part of the Stillwater quadrangle. It seems more probable that after shifting to and fro and beveling the rocks of the plains and spreading thereon their great fans of gravel, with heads at the mouths of the mountain canyons, the distributary channels gathered into less broad though still rather wide valleys tributary to the Yellowstone bottom lands of this early stage and left some of the interstream areas standing higher as ridges.

East of Rock Creek there are high benches bordering the valley which were not mapped by Calvert. The most extensive appears to be No. 2 bench, and above this abrupt erosion slopes rise to a narrow remnant of No. 1 bench. East of Red Lodge No. 2 bench is cut away, and the steep side of the valley rises about 500 feet to the higher bench. About a mile south of the town No. 1 has an altitude of 6,150 feet (barometric). In the next mile it is cut away, and No. 2 bench, which is 200 feet lower, extends to the mountain front. (See pl. 13 *A* and *B*.) Coarse gravel and boulders as much as 2 feet in diameter are exposed in a pit near the head of the upper bench, but nothing was noted suggesting that glacier ice had extended out of the mouth of the canyon onto this high plain. There are remnants of this plain for about 15 miles northeast of Red Lodge on the divide west of Clark Fork of the Yellowstone. One of these examined by the writer south of the Roberts-Bridger road, in sec. 9, T. 6 S., R. 22 E., is 4,850 feet above sea level (barometric)—that is, about 1,200 feet above Clark Fork at Bridger, to the east. This, like the high bench near Red Lodge, is capped with coarse gravel and boulders. Some of the stones are 1 foot in diameter; most are less than 4 inches. They consist principally of gray and pink granite, porphyry, and other dense dark and greenish igneous rocks. The gravel is considerably weathered and in places is cemented by calcium carbonate to conglomerate. About the edges of the flat top the surface is a cobblestone pavement, and the exposed surfaces of the stones are wind-polished and oxidized to a brownish color. No quartzite pebbles similar to those along the Yellowstone farther northwest which were probably derived from the Belt rocks, were found either here or on the high bench near Roscoe.

No ridges appear to rise above the level of this high bench for a long distance to the south nor to the east as far as the Pryor Mountains. There may be some lower remnants of this bench a few miles farther north, between Clark Fork and Elbow Creek west of Fromberg.

Numerous remnants of No. 2 bench were found by the writer farther south up Clark Fork, but none of No. 1 bench, though there may be such remnants closer to the mountain front. If the same altitude and gradient are postulated for No. 1 bench on Clark Fork as those of Polecat Bench, the divide to the southeast, it would stand about 5,000 feet above sea level at the

[44] Calvert, W. R., Geology of the Upper Stillwater Basin, Stillwater and Carbon Counties, Mont.: U. S. Geol. Survey Bull. 641, pl. 20, 1917.

State line—that is, 1,000 feet above the present stream. From this point an average gradient of but 50 feet to the mile for 20 to 25 miles southwestward would extend the bench into the Clark Fork Canyon and connect with the bottom of the broad upper valley at 6,000 to about 6,250 feet. Into the bottom of this ancient valley the inner box canyon has since been cut to a depth of 1,200 feet or more, mostly in granite and gneiss. (See pl. 13 *C*.) This projected No. 1 bench would overtop all the hogbacks of the foothills near and north of Clark Fork, beveling the edges of the upturned Cretaceous and Tertiary formations.

It seems to the writer that this inferred projection is fairly safe, and on that basis the correlation may be extended on up Clark Fork to the pass near Cooke, Mont., near the northeast corner of Yellowstone National Park. It may be concluded, therefore, that near the end of the Tertiary period and perhaps at the beginning of Pleistocene time Clark Fork was flowing southeastward from the vicinity of Cooke in the broad valley whose bottom forms the bench above the inner canyon walls and was issuing at the mountain front onto a broad gravel plain which extended far to the north and which was continuous eastward across the present divide (Polecat Bench) into the Big Horn Basin northeast of Heart Mountain.

A grade of about 10 feet to the mile eastward along the Yellowstone from No. 1 bench near Big Timber and a grade of about 50 feet to the mile northeastward along the tributary valley from No. 1 bench east of Roscoe would cause the two to meet at about 4,200 feet above sea level at the mouth of the Stillwater River near Columbus—that is, No. 1 bench would be at a level 650 feet above the river and 250 feet above the bench on top of the bluff south of Columbus Bridge, which is probably No. 2 bench. If the same grade, 10 feet to the mile, were continued eastward along the Yellowstone 27 miles below Columbus, No. 1 bench near the mouth of Clark Fork would be about 3,900 feet above sea level, or about 600 feet above the river, and here it would be joined by No. 1 bench on Clark Fork if the latter had a grade of about 30 feet to the mile northward from the high bench west of Bridger. Not far from a corresponding altitude (3,900 feet, barometric) are remnants of a bench observed a few miles west of Silesia. A grade not steeper than 10 feet to the mile eastward from Laurel along the Yellowstone River would connect at 3,600 feet with the lower one of the high benches described below (p. 29) crossed east of Billings by the Custer Battlefield Highway.

Decision as to what are probably remnants of No. 1 bench along the lower courses of the Stillwater River, Rock Creek, and Clark Fork depends somewhat on interpretations in the region north of the Pryor and Big Horn Mountains. Here two factors may have tended to hold the streams at relatively high levels—the relatively short distance of the main stream from the Big Horn and Pryor Mountain fronts on the south, and the fact that the edges of the sandstones, those of the Eagle, Judith River, and Lance formations, are crossed by the Yellowstone River between Billings and the Big Horn River on the eastern limb of the Pryor Mountain anticline. None of these sandstones are very hard, yet they are cliff-making rocks as distinguished from the intervening shales, and they tended to retard the deepening of the valley and the widening of its bottom. This effect is well illustrated by present conditions near Billings. The valley for several miles west of Billings is broad, having a maximum width of 7 to 8 miles. In this part the stream has cut through the Eagle sandstone on the top of the anticline and into the underlying Colorado shale. This has facilitated the widening of the valley and caused the recession of the sandstone cliff, which is 350 feet in height on the north. Just east of Billings the sandstone lowers and the ledge swings across to the southeast side. Here the valley is constricted to less than 1 mile in breadth.

There is difficulty in correlating the highest of the high bench remnants east of Billings and north of the Big Horn Mountains with No. 1 bench (Flaxville Plain) nearer the Rocky Mountains and in the Big Horn Basin. In fact, the highest benches are so high as to suggest that they may really have been formed at an earlier stage and may be of Miocene or Oligocene age, as indicated on Plate 1. Either they are earlier or local deformation prior to the development of the second set of terraces raised these benches to disproportionately high altitudes.

BENCHES IN THE CROW INDIAN RESERVATION

In connection with his studies in 1921 Thom mapped the benches in the Crow Indian Reservation, as shown on Plate 1, and he describes them as follows:[45]

> Large areas within the Crow Reservation are covered by deposits of sand, gravel, and boulders which are remnants of flood plains aggraded by streams issuing from the mountains. These flood-plain remnants now appear as terraced surfaces which descend in steplike fashion to the present alluvial valley bottoms of the Big Horn and Yellowstone Rivers. As might be expected, the remnants representing the several terrace levels are of unequal areal extent but seem to indicate a fairly uniform downcutting of 150 to 200 feet between the periods of aggradation. No fossils have been collected from the deposits of terrace gravel in the reservation, and their ages are therefore not definitely known.
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> In the absence of immediate economic interest in the gravel deposits of the reservation the terraces received only incidental study in the course of local stratigraphic or structural work. Therefore, although the conclusions here set forth are believed to be essentially correct, they probably could be made

[45] Thom, W. T., jr., unpublished manuscript.

much more complete and significant after more detailed field work.

There is in general a very close parallelism of gradient between the present streams of the reservation and the older stream-laid terraces, indicating that the periodic downcutting which has taken place has been induced by regional upwarp and not by differential elevation of the mountains with reference to the adjacent plains. As might be expected, the terraces locally blend together, particularly toward the heads of streams where downcutting has been retarded by resistant strata, but in the main the several surfaces are quite distinct and are represented by erosion planes truncating resistant beds as well as by aggraded surfaces.

Following the present writer's suggestion, Thom tentatively correlates the highest bench remnants with the Cypress Hills Oligocene:

The terrace surface tentatively correlated with the Oligocene of the Cypress Hills on the basis of its altitude is well preserved on Pine Ridge, northwest of Hardin, on the plateau west of Fly Creek, and on the ridge between Pryor Creek and the Yellowstone, and a small remnant of it is preserved on the northwest side of the Shively Hill Dome. The reconstructed gradient of this surface accords well with the altitude of the present divide in Pryor Gap (5,260 feet).

These facts and relations of the remnants of benches observed by the present writer in the valley of Clark Fork and in the northern part of the Big Horn Basin, Wyo., lead to the suggestion that the highest benches in the Crow Reservation may have been formed by Clark Fork or an earlier stream heading on the Beartooth Plateau and flowing through the Pryor Gap to join the Yellowstone in Oligocene or Miocene time. Subsequent uplift and accelerated erosion on the shale may have resulted in diversion of this stream westward to the present course of Clark Fork. To quote further from Thom,

This Oligocene (?) terrace is not known to be preserved south of the Big Horn, but its approximate position is apparently indicated by an erosion plane truncating the beds on the higher slopes of the east flank of the Big Horn Mountains and by the eastward-sloping plateau surface of the Wolf and Rosebud Mountains. The tops of the Mowry ridges east and west of Pryor Creek, in the western part of the reservation, also apparently present surviving remnants of this erosional surface.

A second [or intermediate] terrace stage about 200 feet below the Oligocene (?) seems to be fairly well developed in the northwestern part of the reservation along the ridges east of Pryor Creek, and to a lesser extent on the Pryor Creek-Yellowstone divide. This terrace is strikingly developed between the Little Horn and Lodgegrass Creek, and minor remnants of it survive upon the higher buttes along the Rottengrass-Little Horn and Soap Grass-Rottengrass divides and are present at a number of places in the southern part of the reservation. Apparently it was at this stage that the Black Gulch Dome was truncated and that the Mowry and Cloverly ridges on the divides between Soap Creek and the Wyoming line were planed off at their present level.

This intermediate terrace is grouped with No. 1 bench on Plate 1. As indicated by relations, if the highest bench (No. 1) northeast of Cody in the Big Horn Basin were projected down the river it would emerge from the gorge at the northeast flank of the Big Horn Mountains, at an altitude of about 4,000 feet. Thom found large remnants of a gravel-covered bench which stand 400 to 500 feet above what appears to be No. 2 bench along the west side of the Big Horn River from a point near and south of the Chicago, Burlington & Quincy Railroad west of Hardin to the mountains. (See St. Xavier and Fort Custer topographic maps.) The gradient on these remnants increases southward from about 12½ feet to the mile at the north to 100 feet to the mile near the flank of the mountains, 25 miles distant, or at an average rate of 15 feet to the mile. Five miles northwest of the mouth of the lower Big Horn Canyon the bench is about 700 feet above the river and 3,900 feet above sea level.

As shown on Plate 1, this terrace is regarded as the correlative of the Flaxville Plain. Thom states that it

is the one most extensively developed within the reservation. Large gravel-covered uplands belonging to this surface form the even tops of the higher hills west of the Big Horn and south of Williams Coulee, and the same terrace level is well marked both by gravel beds and by erosion surfaces in the valley of East Fork and elsewhere near the site of the former station of Coburn. The Mowry ridge between Woody Creek and the Big Horn River was truncated at this plane, as were the Mowry ridges surrounding the Soap Creek Dome and the Cloverly ridge east of Limekiln Creek. Remnants of the Flaxville (?) are present upon the north end of the Big Horn-Little Horn divide and cover considerable areas on the low part of the Little Horn-Tongue River divide just southwest of Parkman, Wyo.

Thom found another set of terrace remnants about 200 feet below the Flaxville Plain. These perhaps represent the upper level of the No. 2 benches, as grouped by the present writer, west of Clark Fork and along the Yellowstone (p. 53), and they are grouped with No. 2 bench on Plate 1. Thom states that this set

is well developed west of Pryor Creek and to a lesser degree southwest of Hardin. This surface is also well developed in the Beauvais Creek Valley within the Mowry rim, which curves around the north end of the Big Horn Mountains, and within the Mowry hogbacks surrounding the Soap Creek dome.

A set of terraces, which the present writer regards as the correlative of the main or lower level of the second set of terraces on the Yellowstone River (p. 56), is also described by Thom as about 150 feet below his fourth terrace and about the same distance above the present stream grade.

This terrace features the west banks of the Big Horn River and of Pryor Creek and covers a considerable area at the north end of the Big Horn-Little Horn divide. Remnants of it are also present a short distance above stream grade in the Beauvais Creek Valley within the Mowry shale escarpment and within the valleys of most of the other streams of this reservation. Since the development of this terrace the Big Horn has apparently been slowly reducing its area by lateral migration and downcutting, and as a result the river is bordered on one side by a sloping plain descending from the fifth terrace level down to the present alluvial bottom lands, in which the river is slightly intrenched. Hardin is built on this eroded or aggraded surface, which lies principally on the west side of the Big Horn below the Two Legging Bridge and on the east side between the bridge and the mouth of Big Horn Canyon.

Hancock[46] described the high-level deposits of gravel and conglomerate east of Billings and north of the Crow Indian Reservation and suggested that they were laid down at about the same time as the Flaxville gravel of northeastern Montana. Some of the gravel was examined by the present writer in 1921. That north of the road about 10 miles east of Billings, at 3,600 feet above sea level, may represent No. 1 bench. The narrow, flat gravel-capped top of the ridge south of the road rises southward from about 3,850 to 4,000 feet and may be older. The pebbles near the road, the larger ones of which are 6 or 8 inches in longest diameter, are mostly rounded and polished. They appear to have been derived largely from the mountains to the west, inasmuch as there are pebbles of volcanic rock with the granitic pebbles, and also a large percentage of purplish, red, and yellow quartzites similar to those in the bench gravel farther up the Yellowstone River. There are also many pieces of agate, opal (?), chalcedony, and silicified wood. No pebbles of these kinds, excepting the volcanic and granitic rocks, were noted on No. 1 bench east of Roscoe or south of Roberts.

If the grade of the No. 1 or Flaxville bench (Thom's "third terrace" on the Big Horn River) decreased in the 35 miles downstream from the vicinity of Hardin to an average of about 6 feet to the mile, the altitude in the Yellowstone Valley east of Custer would be about 3,300 feet.[47]

This would connect with a grade reduced to 6 to 7 feet to the mile on the Yellowstone east of Huntley, which is about the same as that of the present stream. (See Huntley topographic map.)

NO. 1 OR FLAXVILLE TERRACE ON THE LOWER YELLOWSTONE

The bluff south of Myers station, which is about 14 miles below the mouth of the Big Horn River, rises about 600 feet above the river, or to an altitude of 3,300 feet. Here the top of the sandstone is capped with a thick bed of gravel. This is probably a remnant of No. 1 bench.

Rogers and Lee[48] describe deposits of coarse gravel on the ridge between Tullock and Sarpy Creeks east of the mouth of the Big Horn River. On the north ends of the main divides there are said to be several well-marked benches at lower altitudes, but the highest of the deposits, at 3,700 to 3,800 feet, or about 1,100 feet above the streams, appear to form a monotonous series of bare, rounded hills, due to erosion of bench gravel and the underlying soft Lebo shale. Some of this gravel was examined by the present writer and found to consist of pebbles of the same kinds of rock as occur on Pine Ridge and the other high benches east of Billings. Doubtless some of the gravel is to be correlated with the Flaxville gravel of No. 1 bench.

Dobbin[49] states that the northern edge of the Oligocene or Miocene (?) gravel deposits described on page 12 is about 12 miles south of the terrace along the Yellowstone River near Forsyth and that the vertical interval between them is 900 to 1,000 feet. The intervening area is covered with a mantle of gravel which is not arranged in any well-defined system of terraces and has been reworked so many times that its relations are obscure. A small remnant of a terrace with gravel locally cemented to a conglomerate 10 feet thick, in the central part of T. 5 N., R. 41 E., stands 700 feet above the river. If the higher gravel corresponds to that on the Cypress Hills, this may correspond to the Flaxville gravel. Where the gravel overlies the Bearpaw shale it gives rise to rounded hills and a monotonous landscape. It makes prominent benches on the divides where it overlies rocks of the Lance formation and is usually covered with a scanty growth of pine trees.

With the exception of the examination of the gravel-capped hills between Tullock and Sarpy Creeks south of Hysham, described above, no search of the area south of the Yellowstone River and east of the Big Horn River for remnants of No. 1 bench has been made by the writer. Parts of the area east of the Tongue River have been examined by Collier and Smith,[50] Herald,[51] Bowen,[52] Bauer,[53] Wegemann,[54] and Rowe and Wilson,[55] but their reports do not describe any gravel-capped benches which can properly be correlated with No. 1 bench as here described.

Nowhere west of Miles City are any remnants of No. 1 bench known to occur on the north side of the Yellowstone River, except those near the Crazy Moun-

[46] Hancock, E. T., Geology and oil prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pp. 128–129, 1919.

[47] According to the Fort Custer and St. Xavier topographic maps, the present average grade of the Big Horn River for 52 miles below the mouth of the canyon is a little less than 10 feet to the mile, minor bends being neglected.

[48] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 749, pp. 44–47, 1923.

[49] Dobbin, C. E., The Forsyth coal field, Mont.: U. S. Geol. Survey Bull. 812, p. 21, 1929.

[50] Collier, A. J., and Smith, C. D., The Miles City coal field, Mont.: U. S. Geol. Survey Bull. 341, pp. 36–61, 1909.

[51] Herald, F. A., The Terry lignite field, Custer County, Mont.: U. S. Geol. Survey Bull. 471, pp. 227–270, 1912.

[52] Bowen, C. F., The Baker lignite field, Custer County, Mont.: Idem, pp. 202–226.

[53] Bauer, C. M., The Ekalaka lignite field, southeastern Montana: U. S. Geol. Survey Bull. 751, pp. 231–267, 1925.

[54] Wegemann, C. H., Notes on the coals of the Custer National Forest, Mont.: U. S. Geol. Survey Bull. 381, pp. 108–114, 1910.

[55] Rowe, J. P., and Wilson, R. A., Geology and economic deposits of a portion of eastern Montana: Montana Univ. Studies, ser. 1, 58 pp., 1916.

tains, described above. Northeast of Miles City, however, it appears that the Yellowstone spread gravel very widely on No. 1 bench west and northwest of its present course.

In 1911 Rogers studied the Little Sheep Mountain coal field north of Yellowstone River in what is now Prairie County. He describes the gravel-covered benches as follows:[56]

> The dissected remnants of at least three old river terraces may be recognized. The highest terrace lies on the southeast flank of Little Sheep Mountain at an altitude of 3,200 feet, and there is another on the north divide of Cherry Creek at an altitude of about 2,800 feet [No. 2]. This high terrace is probably also represented in T. 10 N., R. 45 E., where a considerable area is covered by alluvium at an altitude only slightly greater than either of those mentioned above. The third terrace is best preserved near the bank of Yellowstone River in T. 10 N., R. 49 E., where its altitude is 2,550 feet. In these places and in the others where the terraces may be recognized they are covered with a 20 or 25 foot layer of alluvial pebbles with an interstitial filling of fine gravel, sand, and silt. * * *
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> The pebbles on these terraces are well waterworn and usually more or less flattened; their greatest diameter is commonly as much as 6 inches. The interstitial sand is chiefly quartz, generally in angular grains. An examination of the pebbles covering an area of about a square yard resulted in the identification of the following: Quartzite, vein quartz, jasper and chalcedony, sandstone, quartz conglomerate, granite, trachyte, and olivine basalt.

In 1921 the present writer drove from Miles City north to Crow Rock post office and thence down Cherry Creek Valley to Terry. On this trip no well-preserved flat benches were observed, but gravel very similar to that on the high benches farther west was found at several places up to the highest altitude reached, 3,100 to 3,200 feet (barometric). The pebbles are in the main smoothly rounded and have a maximum diameter of 10 inches, though mostly about 2 inches or smaller. They consist generally of very resistant rocks, such as were noted by Rogers, with but few granitic rocks, sparse deeply etched fragments of Paleozoic limestone, and many pieces of silicified wood. One deposit at an altitude of 2,875 feet is partly cemented to a hard conglomerate. This may be a remnant of No. 2 bench.

In 1920 the writer made a brief reconnaissance of parts of the Glendive quadrangle and found several erosional remnants of a high gravel bench which is probably to be correlated with the Flaxville Plain as of Miocene or Pliocene age. Studies of 1921 and 1922 tended to confirm the opinion that this is the same as No. 1 bench farther west. (See pls. 1 and 28.) As shown on the topographic map, these high benches occur in a belt between 6 and 20 miles west of the Yellowstone River; where they form the flat tops of eight or nine ridges intervening between parallel southeastward-flowing intermittent streams. The ridges are sharply truncated at their southeast ends by steep slopes which drop several hundred feet to remnants of lower benches. The smooth, flat tops of the ridges range in width from less than 1 mile to 6 miles and are sharply delimited by the steep side slopes of the intervening valleys or coulees, some of which are 300 to 400 feet in depth. One of these valleys is traversed by the Richey branch of the Great Northern Railway. This road crosses the divide at Enid, at an altitude of 2,450 feet, through a broad, flat-bottomed pass 300 feet in depth. The southeast ends of these benches are about 2,700 to 2,800 feet above sea level, or 700 feet above the Yellowstone River, and from this level they rise gradually to an altitude of 3,000 feet on the narrow-crested divide that separates tributaries of the Yellowstone from those of Redwater Creek, which joins the Missouri near Poplar. The tops of most of the ridges have, however, been narrowed and lowered by erosion so as to leave gaps of several miles between the benches and the divide.

The loamy soil on these high benches is underlain by gravel, 5 to 15 feet of which is exposed at the tops of the marginal slopes. The pebbles, which consist of various dense igneous and volcanic rocks, quartz, quartzite, and a few pieces of chalcedonized wood, are mostly less than 3 inches in diameter and have smoothly rounded waterworn surfaces. There are also a few larger pebbles 5 or 6 inches in diameter. The gravel is not so coarse as that on the lowest terraces near the river. There are fewer pebbles of quartzite and more of crystalline rocks than on the Flaxville Plain and the Cypress Hills, to the northwest. The crystalline rocks are not, however, granite, such as is seen in the glacial drift on the lower benches at and north of Intake ("Headworks" on Glendive topographic map). This is evidently stream gravel which came down the Yellowstone Valley from the mountains, over 300 miles to the west. Some of it, perhaps, came from the Big Horn Mountains of Wyoming. A few granite boulders were seen near the east end of the top of the high bench northwest of Intake, in T. 19 N., R. 56 E. It is possible, however, that the ice of the glacial lobe which extended south, up the valley to Intake, crowded up onto the edge of the high bench and left these boulders there.

The most northerly remnant of No. 1 bench noted in the Glendive quadrangle is about 12 miles west of Sidney and 3 to 5 miles east of Three Buttes, in T. 23 N., R. 56 E. This stands at an altitude of 2,650 feet, about 700 feet above the Yellowstone River, and very little of the crest of the old divide to the northwest rises above this level. The crest of the ridge at Sioux Pass is very close to this altitude, but no gravel was seen upon it.

[56] Rogers, G. S., The Little Sheep Mountain coal field, Dawson, Custer, and Rosebud Counties, Mont., U. S. Geol. Survey Bull. 531, pp. 161–162, 165, 1913.

From these descriptions it appears that at the time of the formation of the Flaxville Plain or No. 1 bench the Yellowstone and Missouri Rivers near their junction must have been flowing at a level which is now about 2,500 feet above the sea—that is, 600 feet above the present channels. In the 280 miles from the high bench at 3,600 feet east of Billings to this level of 2,500 feet at the junction of the Missouri and Yellowstone the average grade or slope would be about 4 feet to the mile. This gradient is somewhat higher than that of the present stream, even if the numerous meanders are neglected. At present the average fall on the Yellowstone River in 280 miles below Huntley is about 3.6 feet to the mile, disregarding bends. In the same distance along the old course of the Missouri River between Havre and the mouth of the Yellowstone the fall would be about 3 feet to the mile if the bench near Harlem was at 3,000 feet, as described above.

Comparison shows that No. 1 bench on the Yellowstone is sufficiently high to have extended northeastward from the site of the present mouth of the stream along the line of the Missouri Valley to Williston and thence up the course of Little Muddy Creek (reversed), and to have crossed the Coteau du Missouri in the region of Crosby, N. Dak. There is, therefore, nothing in the relations of No. 1 bench so far as known, or in those of its correlative, the Flaxville Plain, antagonistic to the idea that in preglacial time the waters of the Missouri and Yellowstone Rivers flowed northeastward to Hudson Bay or its marine predecessor.

PLIOCENE AND EARLY PLEISTOCENE EPOCHS

GENERAL RELATIONS

In 1911 the writer described,[58] before the Geological Society of America, the occurrence of very old glacial till capping the high benches in front of the mountains of Glacier National Park, and in 1912 Stebinger and the writer [59] presented a second paper on the same subject. This glacial till, some of which is cemented by calcium carbonate to a hard tillite, caps the highest (No. 1) bench, which is now regarded as the physiographic correlative of the Flaxville Plain of northeastern Montana. The geographic and physiographic relations of this ancient till and of striated pebbles scattered on No. 1 and No. 2 benches for 20 miles out from the mountain front are such as to indicate that the first of the mountain glaciers extended out onto the No. 1 bench before that surface had been greatly dissected. It has been suggested that the striated pebbles on No. 2 bench were deposited by a second and later advance of the mountain glaciers, but this has not been demonstrated. That the high-level glacial till is very old, probably as old as the Kansan or Nebraskan drift of Iowa and adjacent States, is indicated by the fact that before the mountain glaciers advanced at the Wisconsin stage the mountain gorges and their valley continuations on the adjacent plain had been deepened 1,000 feet or more, largely by interglacial stream erosion, so that the relief of the mesas capped with till and gravel controlled to a considerable extent the later glacial flow.

Careful consideration of the relations of the terrace remnants along the upper Missouri and Yellowstone and their tributaries to the remnants of the high plains bordering the mountain fronts and to the ancient glacial till on the highest of these remnants in the Glacier National Park region seems to warrant certain tentative conclusions, which may be summarized as follows:

1. The highest of the benches or terraces bordering the mountain fronts are correlatives of the Flaxville Plain of northeastern Montana.

2. Such fossils as have been found in the Flaxville gravel indicate that the development of the Flaxville Plain was not completed before Pliocene time.

3. The presence of the *Camelops* tooth, which was identified by Gidley as "apparently Pleistocene," suggests that the streams may not have finished deposition of the Flaxville gravel until early Pleistocene time.

4. The relations of the oldest drift of the mountain glaciers on the supposed remnants of the Flaxville Plain close to the mountain front lead to the inference that the Flaxville Plain had not been greatly dissected when climatic conditions became such as to bring on extensive glaciation in the mountains.

5. The first Cordilleran glaciation was probably contemporaneous with the advance of the Keewatin ice sheet of the Nebraskan stage and is regarded as marking the beginning of Pleistocene time.

6. About this time the streams began cutting below the Flaxville Plain, and this, taken in connection with the beginning of Cordilleran glaciation, leads to the inference that Pleistocene time in this region was initiated by a second regional uplift. The amount and character of this uplift are described below.

7. The writer knows of no observational evidence for regarding as Pleistocene any features in this region that are older than the pre-Wisconsin glacial drift on the remnants of the Flaxville Plain in front of the mountains of Glacier National Park.

In eastern Nebraska and western Iowa the relations of the early Pleistocene drift sheets to the underlying eroded surface of the Cretaceous, Oligocene, and Miocene deposits, so far as known, are such as to indicate that a large amount of erosion had been accomplished

[58] Alden, W. C., Pre-Wisconsin glacial drift in the region of Glacier National Park, Mont.: Geol. Soc. America Bull., vol. 23, pp. 687–708, 1912.

[59] Alden, W. C., and Stebinger, Eugene, Pre-Wisconsin glacial drift in the region of Glacier National Park, Mont.: Idem, vol. 24, pp. 529–572, 1913.

by the Missouri River in that part of its course south of South Dakota between Miocene and early Pleistocene time.

The apparent conflict between the evidence from (1) the region bordering the Missouri River in eastern Nebraska and western Iowa, (2) the region of the Missouri River and the Flaxville Plain in eastern Montana, and (3) the relations of the high-level glacial drift on the No. 1 benches in the region of Glacier National Park has led the writer to the further tentative conclusions stated below:

A certain amount of regional uplift probably took place in Pliocene time. The lower Missouri followed its present course south of southeastern South Dakota, but for some distance north of this latitude in South Dakota, perhaps as far as Mitchell (see Todd)[60] it was flowing in the preglacial valley of the James River east of the Coteau du Missouri, the present channel below Williston, N. Dak., past Bismarck, Pierre, and Yankton not having yet been adopted. The Yellowstone and the Upper Missouri were still flowing northeastward across the Coteau du Missouri toward Hudson Bay. As a consequence of the uplift these streams cut below the level of the Flaxville Plain and the No. 1 terrace on the Yellowstone and its tributaries and then began anew the process of planation at a lower level, thus developing the No. 2 benches described below. In eastern Montana and in the adjacent part of Canada the dissection and planation may have proceeded to a considerable extent before it was interrupted by the early Pleistocene continental glaciation. In the Glacier National Park region and the mountains to the south the uplift may have been less than to the east, erosion had not proceeded so far, and No. 1 bench was cut to only a moderate depth (100 to 200 feet ?), though it may have been worn away in considerable areas by the process of lateral planation before this was interrupted by the development of mountain glaciers and their extension onto the plain bordering the mountain front. Both the No. 1 and No. 2 benches carry old glacial drift near the mountain front in the Blackfeet Indian Reservation.

Certainly the mountain streams had not cut below the planated surface of the upper level of the second set of terraces before the mountain glaciers extended onto it and left the cap of drift, though it is possible that No. 1 bench had been somewhat eroded before any of the glaciers reached it. The drift on the two levels may belong to one and the same stage, or it may comprise deposits of two different stages, to be correlated with the Nebraskan and Kansan stages of eastern Nebraska and Iowa. It seems probable that in eastern Montana erosion had cut below the Flaxville Plain (Miocene or Pliocene) and below No. 1 bench on the Yellowstone River and its tributaries and had developed or was developing the upper level of the second set of terraces before the first continental ice invaded North Dakota and interfered with the northeastward discharge of the rivers.

[60] Todd, J. E., The Pleistocene history of the Missouri River: Science, new ser., vol. 39, p. 268, 1914.

QUATERNARY PERIOD

PLEISTOCENE EPOCH

EARLY PLEISTOCENE MOUNTAIN GLACIATION ON NO. 1 AND NO. 2 BENCHES

It will scarcely be questioned that the earliest known glaciation of this region was of Pleistocene age. This being the case, it is the opinion of the writer that among the oldest Pleistocene deposits in the region are the caps of glacial drift on the highest levels of the plains near the mountain front, No. 1 and No. 2 benches, in the Glacier National Park region. (See pl. 1.) These deposits were described by the writer and Eugene Stebinger in the papers cited above. They include the "Kennedy gravels," described by Bailey Willis[61] from the field notes of George I. Finlay and doubtfully referred by him to the Pleistocene. They also include a part of the "quartzite gravels" described by Calhoun[62] and regarded by him as of preglacial age.

The geologic importance of such high-level deposits of early Pleistocene glacial drift and the rarity of their preservation in the mountains of the West seems to warrant considerable detail of description. The character and relations of these deposits are set forth below in the order of their occurrence from north to south. (See pls. 1 and 37.)

GLACIAL DRIFT ON MAKOWAN BUTTE, ALBERTA

In southern Alberta between the Belly River on the west and the head of Lee Creek on the east a high ridge, known as Makowan Butte,[63] extends northward to a point 5 miles north of the international boundary. At the abrupt north end this ridge stands about 1,300 feet above the Belly River, or about 5,750 feet above sea level. It is capped with about 100 feet of glacial drift, which is exposed in several places in scarps left by landslides on the underlying Cretaceous or Tertiary clay and shale. The drift is composed of angular to subangular or well-rounded pebbles and boulders as much as 5 feet in length, representing the several kinds of rock from the mountains, embedded in a

[61] Willis, Bailey, Stratigraphy and structure of the Lewis and Livingston Ranges, Mont.: Geol. Soc. America Bull., vol. 13, pp. 328–330, 1902.

[62] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, pp. 13, 49–52, 1906.

[63] See map of Waterton Lakes Park, Alberta, Dept. Interior, Canada. This ridge was designated Belly River Ridge in the paper by Alden and Stebinger, in 1913. Its southward continuation in the United States is Lee Ridge. (See map of Glacier National Park: U. S. Geol. Survey Bull. 600, pl. 13, 1914.)

matrix of clay. Glacially scored stones are not abundant, but search resulted in finding numerous well-striated pebbles of greenish argillite. In the upper part of the ridge there are almost no pieces of limestone, though these are plentiful lower down. Evidently the limestone pebbles have been removed from the higher levels by solution, and ledges of tillite that crop out 10 to 15 feet below the top of the section show the results of cementation by the calcium carbonate carried down by percolating waters.

Drift of the same character is found 8 to 10 miles farther south on this same ridge, west of Chief Mountain, at 6,000 to 6,300 feet above the sea.

These deposits are well above the upper limit of the Belly River Glacier of the Wisconsin stage, although, as determined by C. S. Corbett in 1914, a small tongue of that ice spilled over the sag in the crest of the ridge at the international boundary and extended a few miles down the valley of Lee Creek on the east. In Corbett's field notes is the following description of the high-level drift on the ridge just north of Gable Mountain, at a point near the Belly River trail 4 miles west of Chief Mountain.

At 6,520 feet (barometric), top of cut.

Broad cut showing exposure of drift about 200 feet high. About 25 feet below the top is an exposure of the subsurface material, which is tillite. The clayey matrix is so indurated it rings when struck with the hammer. The boulders and pebbles are probably over 90 per cent of limestone, most of which show the characteristics of the Altyn formation. Some of these limestone pebbles retain glacial striae. They range in size up to 8 feet in diameter. A few red and green argillite pebbles were found—no diorite or lava. Also no Colorado shale material noted.

Benches on the west side of the Belly River Valley were examined in 1911 by J. Elmer Thomas and the present writer; they are described as follows:

Between 5,750 and 5,950 feet above the sea, or between 1,000 and 1,200 feet above the valley bottom, is a bare scarp face, the marginal slope of a shoulder standing out on the slope. The material exposed in this scarp is glacial till. All the pre-Cambrian formations are represented in the pebbles and boulders of this drift—limestone, red and white quartzite, diorite, and amygdaloidal trap. Many of the argillite pebbles are well striated. Numerous blocks of tillite were observed, but no ledges were seen in place. Above the scarp the bench rises westward to the base of the cliff of pre-Cambrian rock, but with a slope much less steep than the general slope of the valley wall below. A similar bench, but somewhat less well marked, occurs to the north just across the ravine. No exposures were seen to show whether or not this bench is on a deposit of till. Seen from the east side of the bottom of the valley, the two appear to be parts of one bench, cut through by a broad sag, in the bottom of which is a sharp V-shaped ravine that drains two glacial cirques in the mountain slope above. This relation, taken together with the form of the bench and the character of the underlying deposit, suggests that the drift composing the bench was deposited under the same conditions as that capping the flat-topped ridges and mesas at a pre-Wisconsin stage of glaciation; that during the later extension of the Belly River glacier a tributary ice stream, heading in the cirques above, cut through the bench, forming the broad sag; and that, after the melting of this glacier and that in the valley, post-glacial drainage cut the sharp notch.

At a point about half a mile south of the international boundary there is a similar bench remnant at about the same altitude, with an exposure in the steep marginal slope, showing glacial till similar to that described above. The sides of the valley are heavily wooded and no detailed examination of them was made, so that the upper limit of the last glaciation was not determined. It is doubtful if the ice overlapped these high-level deposits. These benches stand like remnants of high-level terraces and appear to represent a former stage in the development of the valley. They probably belong to the second set.

In 1914 C. S. Corbett and Campbell R. Williams determined that the Kennedy Creek Glacier at the Wisconsin stage spilled over the col, 300 feet deep, 2 or 3 miles east of Chief Mountain and extended a small lobe northward or down the valley of the East Fork of Lee Creek to a point within a mile of the international boundary, but the ice barely overtopped the south end of the high bench on the east side of the col at 5,900 feet above sea level. Corbett concluded that the 75 feet of till exposed at the south end is probably of Wisconsin age, as it is fresh looking and contains plenty of striated limestone pebbles. This till forms a sharp-crested little ridge about 50 feet lower than the point of the main flat top (at 5,950 feet), which slopes gently down northeastward as the remnant of an old high bench. On this bench only green argillite pebbles retain striae.

DRIFT ON KENNEDY RIDGE

North of the North Fork of Kennedy Creek, in the area east of Chief Mountain, is a hilly tract underlain by Cretaceous sandstone. Rising above the general level of this tract, just north of Kennedy Creek, is a small, abrupt, flat-topped mesa having an altitude of 5,800 feet above sea level, or 900 feet above the stream on the south. (See pl. 14 *B*.) This was described by Willis[64] as "the typical occurrence of the Kennedy gravels." The slopes of this mesa are abrupt scarps due to landslides, and in places these scarp faces are bare of vegetation and give good exposures of the component material, 100 feet or more in height.

[64] Willis, Bailey, op. cit., pp. 328–330.

This material is coarse cobblestone gravel and small boulders. A large part of the stones are subangular and faceted, and some of them are well rounded. No evidence of assortment or bedding was notd, and, to the writer, the aspect was rather that of gravelly glacial drift than of stream gravel. Moreover, careful search yielded numerous pebbles carrying striations. (See pl. 15 *A*.) The stones, which are wholly pre-Cambrian rock from the mounutains, consist principally of buff limestone and quartzitic material from the Altyn limestone, and with this is a subordinate amount of red and green argillite. Striations were found only on pieces of the greenish dense quartzitic argillite. The surfaces of other pebbles had been sufficiently etched and roughened by weathering to remove striations if any were present. The ridge stands so high and is so narrow and so exposed on all sides that conditions particularly favor the surficial modification of the material by the agencies of weathering. Three small knobs about 3 miles farther north are capped with the Pre-Wisconsin drift at 5,300 to 5,500 feet above sea level.

DRIFT ON SWIFTCURRENT RIDGE

The ridge between the South Fork of Kennedy Creek and Swiftcurrent Creek, on the north side of the Sherburne Lakes Reservoir, is known as Swiftcurrent Ridge. A subordinate part of this ridge extends northward at right angles to the main ridge from the Swiftcurrent Valley and forms the divide between the St. Mary River on the east and the South Fork of Kennedy Creek on the west. The subordinate ridge, which rises 650 to 850 feet above the bottom of the valley on the east, appears to have been overtopped by the St. Mary Glacier of the Wisconsin stage, inasmuch as morainal material is found on its crest. The summit of the main ridge, which trends in a general east-west direction, appears not to have been overtopped by the later ice moving down the valleys of either Swiftcurrent Creek or the South Fork of Kennedy Creek. For 2½ miles the top of this ridge is nearly flat (pl. 14 *A*) and has a width of about 600 yards. It gradually increases in altitude from about 5,800 feet above sea level at the east to 6,000 feet at the west, so that it stands about 1,150 to 1,250 feet above Swiftcurrent Creek on the south. From this top steep slopes decline on both sides. At the top of the south slope is an abrupt scarp due to landsliding. This has a height of 200 to 300 feet, and below is an uneven slope marked by swells and sags and numerous small lakelets. This slope resembles morainal topography but is probably due principally to slumping of the drift over the soft Cretaceous shale. At least 200 feet of glacial till is exposed in the clean scarp faces at the top of the slope. This drift is of the same composition and appearance as that on the ridge across the valley to the south, except that here, in addition to the other ingredients, fragments of Siyeh limestone and amygdaloidal trap rock are found. The trap rock is present in the mountains at the head of the Swiftcurrent Valley. Many of the pebbles and boulders are striated. Blocks of the tillite were seen, but no ledges clearly in place. Part of the diorite boulders are considerably weathered so as to be exfoliating shells half an inch thick, and some of the limestone pebbles in the upper part of the drift are etched but not removed by solution.

At the west end of the high tract just described the ridge narrows and the crest is broken by a sag about 1¼ miles in length. This part is crossed by the boundary between the Blackfeet Indian Reservation and Glacier National Park. Here the drift cap has been removed and in places the Cretaceous shale is exposed. Beyond this locality the crest again rises and a narrow remnant of the old drift remains. This part of the ridge was examined by J. E. Thomas but not seen by the writer. Mr. Thomas reports a notched flat crest rising from 6,100 to 6,200 feet above the sea, and scarps giving good exposures of 200 feet of glacial drift like that forming the top of the ridge farther east, with ledges of tillite in place. On the surface boulders of diorite and amygdaloidal trap are conspicuous, some being 4 to 6 feet in length. The drift was observed in place within a few hundred feet of the pre-Cambrian Altyn limestone in the east end of Appekunny Mountain. West of a notch there is an abrupt rise to a bench at 6,300 feet above the sea. This is cut in solid limestone and extends for a short distance about the north side of the point of the mountain. On this bench no drift was found. The top of the drift stands nearly 1,500 feet above Swiftcurrent Creek on the south and 800 feet above the South Fork of Kennedy Creek on the north.

DRIFT ON BOULDER RIDGE

On the crest of the ridge of Cretaceous shale between Boulder and Swiftcurrent Creeks is glacial till which appears to be 200 feet or more in thickness. It is exposed in scarps due to slumping at two or three places at the tops of the north and south slopes. The pebbles and boulders in the reddish till are of limestone, red and green argillite, quartzite, and diorite and are well faceted and striated. Ledges of tillite due to cementation protrude from the drift slope, but there is no other notable evidence of weathering, and limestone pebbles are present nearly or quite to the top. The top of this highest part of Boulder Ridge is notably flat and has a length of about 2 miles. In this length the altitude increases southwestward toward the mountain from about 6,100 to 6,300 feet. It thus stands 600 to 800 feet above Boulder Creek on the south and 1,400 to 1,600 feet above the Sherburne

Lakes Reservoir in the Swiftcurrent Valley on the north. At the southwest end of this flat top a short sharp ridge rises to an altitude of 6,400 feet. The rise does not continue to the front of Point Mountain, but after reaching this high altitude the crest drops abruptly to a notch 200 feet or more in depth, beyond which it again rises to Point Mountain. This sharp, highest part of the crest of Boulder Ridge consists of angular fragments of limestone, white quartzite, and red and green argillite, such as compose Point Mountain. No fragments of diorite were noted. The material does not look like glacial drift but like talus, and its character and relations lead to the suggestion that here is the last remnant of a disintegrated salient of Point Mountain, which at the time of the deposition of the high-level drift extended 1¼ miles farther to the northeastward than it does at present. The fragmental material came from the pre-Cambrian formations, which in the nearest part of Point Mountain lie more than 800 feet higher than this remnant. This relationship indicates either that the pre-Cambrian rock of this remnant was let down from a higher level by gradual slumping or washing away of the underlying Cretaceous shale, or that, owing to a slight anticlinal fold, it originally stood lower at this point than it does in Point Mountain, 1¼ miles away, where the rock is now inclined upward in the direction of the remnant. Owing to similarity in component material of the older and younger drift and to the slumped and wooded condition of the slopes it is difficult to determine just how high on the flanks of Boulder Ridge the ice of the Boulder Creek and Swiftcurrent Glaciers extended at the Wisconsin stage of glaciation. It seems clear, however, that the later ice did not overtop the higher part of the ridge, that is, No. 1 bench, but that it did override No. 2 bench, 125 feet lower, which is developed on the eastern part of the crest.

It is of interest to note in this connection that in 1914 C. S. Corbett found glacial striae on the crest of Point Mountain above the west end of Boulder Ridge, at 8,300 feet above sea level, trending N. 30° E. and N. 60° E., which he regarded as the product of pre-Wisconsin glaciation.

DRIFT ON RIDGE WEST OF LOWER ST. MARY LAKE

On the west side of Lower St. Mary Lake a ridge of Cretaceous shale and sandstone lies between the lake on the east and Flattop Mountain and the Boulder Creek Valley on the west. The crest of the ridge is narrow and serrate, consisting of a row of sharp hills extending north and south on the line between secs. 16 and 17, T. 35 N., R. 14 W. These peaks stand 5,700 to 5,900 feet above sea level, 1,200 to 1,400 feet above the lake, and 500 to 700 feet above Boulder Creek. There is no very good exposure, but the material seen on the surfaces of the knobs is like that of the drift described above. M. R. Campbell reported that he found tillite on top of one of the hills. It is probable that this is a remnant of the pre-Wisconsin drift. The surface of the ridge surrounding the line of hills is marked by low swells and sags, the result of later drift deposition or of landsliding or a combination of both.

DRIFT ON ST. MARY RIDGE

Emerging from the mountains between the bold salients known as Divide Mountain and Singleshot Mountain, the waters of the St. Mary River flow in a general direction nearly due north through the lower lake and beyond across the international boundary. Bordering the lower lake and the lower part of the upper lake on the east is an undulating tract about a mile in width composed of small hills and ridges of shale mantled with later glacial drift and standing 100 to 300 feet above the lake levels. From this a steep slope, most of which is heavily timbered, rises eastward to the crest of a broad ridge known as St. Mary Ridge. The crest of this ridge declines gradually in altitude from south to north. It is highest between 2 and 3 miles north of Divide Mountain, there standing about 6,100 feet above sea level. In the interval between this highest part and the mountain there is a broad sag in the crest line where the top of the ridge is 300 feet lower. Where highest the top of St. Mary Ridge stands over 1,600 feet above the level of the upper lake. From this highest part the northward decline carries the crest line down to a level which, east of the foot of the lower lake, between 9 and 10 miles to the north, is about 1,100 feet above the water in this lake and 5,500 feet above sea level. Duck Lake lies in a big sag in the upland, so that the crest of the ridge may be said to curve eastward on the south side of this lake. The top of St. Mary Ridge is broad and smooth, and from it the plain slopes gradually eastward. Much of this surface has been lowered by erosion by the headwaters of tributaries of the Milk River, but in the interstream areas the higher tracts comprise remnants of the No. 1 and No. 2 benches.

North of the broad sag in which lies Duck Lake the Hudson Bay divide continues as a broad high ridge similar to and really a part of St. Mary Ridge.

On the steep west slope of St. Mary Ridge there has been considerable landsliding on the shale, which probably forms the bulk of the ridge. At a few places near the top of the slope this slumping has produced fresh scarps, giving excellent exposures of the material capping the ridge. Following the old trail southeastward from the foot of Upper St. Mary Lake for about 1½ miles and then climbing the wooded slope, the writer reached one of these scarps between 1,100 and 1,400 feet above the lake. The exposure has a height of nearly 300 feet and a length of 500 feet or more. The upper 30 to 50 feet of the section is grayish glacial till, in which the pebbles and boulders consist of red and green argillite, quartzite, gray siliceous limestone from the Siyeh formation, diorite, and some buff limestone from the Altyn formation. It looks as if most of the Altyn limestone pebbles had been removed by solution, and fragments of the Siyeh limestone are deeply etched. Beneath this is a 10 to 15 foot band in which the till is oxidized to an orange or yellowish tint. In this is more of the yellow oxidized limestone, some of the fragments of which are thoroughly rotted. Underlying this zone and forming the greater part of the section is reddish till cemented by calcium carbonate to a hard conglomerate which projects from the slope as ledges. Most of the pebbles and boulders in this conglomerate have fresh glaciated surfaces, but some of the diorites are disintegrating; many of the buff limestones are etched by solution, and some have been removed, leaving only a yellowish powder in the cavities. The reddish tint is due to the large amount of red argillite. The calcium carbonate cement was probably derived by percolating waters from the solution of limestone fragments in the upper part of the section. It is the projecting ledges of conglomerate which give to the deposit, as seen from the valley below, the appearance of stratification. Close examination reveals no assortment of the material or bedding. No fragments of rock were noted other than such as are derived from the mountains. About 250 feet of drift was seen, but the base was not exposed. About half a mile farther south an exposure of similar material was examined. Here the yellow band was not so noticeable, but other evidences of weathering and cementation are the same. Four miles north of this scarp a third exposure was examined by J. E. Thomas, who reports 250 feet of drift of much the same composition as noted above. No limestone was noted at the top, though blocks of Siyeh limestone were seen in the conglomerate, which extends within 5 or 10 feet of the grassed top.

From the material exposed at these points it is apparent that the cap of St. Mary Ridge is old glacial drift. Owing to the thick woods and the large amount of landsliding on the southern half of the steep slope, the upper limit reached by the St. Mary Glacier of the Wisconsin stage could not be determined there. Farther north, about a mile south of the point where the ridge is crossed by the Babb-Browning road, a small but definite morainal ridge begins to be developed somewhat below the crest of the smoothly curved top of the big ridge. This small drift ridge, which is evidently the lateral moraine of the St. Mary Glacier, was traversed for about 3 miles and found to be increasing in size toward the north. South of Duck Lake this ridge curves eastward with the crest of the big ridge. This moraine carries plentiful blocks of limestone, but on the smooth broad top to the east little else than quartzite pebbles was noted. As determined from the sections described, these quartzite pebbles represent the insoluble weathered residual material at the top of the older drift. Taking everything into consideration, it is clear that the thick drift forming the cap of St. Mary Ridge can not be referred to the last St. Mary Glacier, although that ice stream so far filled the valley as to overtop the high slope of the ridge east of the lower lake.

In 1912 the writer found an excellent exposure of the drift on the east side of St. Mary Ridge. In the woods on the north slope of the valley of one of the branches of Livermore Creek which cuts the east slope of the big ridge 6 miles due west of Horse Lake, in the SE. ¼ sec. 6, T. 34 N., R. 13 W., between 5,700 and 5,800 feet above the sea, was a clean scarp due to slumping on the underlying Cretaceous shale. The scarp was about 75 yards long and had a maximum height of about 25 feet. In the western half of the exposure the upper 10 to 12 feet consisted of sand and gravel interstratified with glacial till; below this was 15 feet of coarse, bouldery till. (See pl. 15 *B*.) Some of the striated boulders in this till were 5 to 6 feet in length. The pebbles and boulders were derived exclusively from the mountain rocks, mostly quartzite and red and green argillite, with some of diorite and some from the Siyeh and Altyn limestones. Many of the limestone pebbles in the upper part of the section were rotted to a loose buff powder, as the result of solution. In places streaks of stratified sand were cemented to hard sandstone, and below the upper 5 feet the till was cemented to a hard tillite by the calcium carbonate redeposited by the downward-percolating waters.

Examination showed also that the flat top on that part of the Hudson Bay divide between a point south of Spider Lake and the gap near Galbraith's ranch, south of the United States customhouse, well above the marginal moraine of St. Mary Glacier, is capped in the western part by 15 to 25 feet or more of glacial till, and farther east by thin gravelly drift containing striated pebbles of greenish argillite. (See pl. 15 *B*.) The superficial deposits on that part east of the gap near Galbraith's ranch were not carefully examined. The top of the ridge where capped with this drift declines eastward in 5 miles from 5,300 feet above sea level to 5,100 feet. The marginal moraine of the St. Mary Glacier, looping back to the northwest on the north side of Goose Lake (pls. 1 and 37), crosses the highest part of the ridge at the west end, doubles sharply back to an east-northeasterly trend, and gradually descends the steep north slope of the ridge until it lies on the plain several hundred feet below the drift on the top of the divide. (See fig. 1.) It is thus clear that the drift on the divide is not referable to the Wisconsin stage of glaciation. The altitude of the top of the ridge shows that it is correlative with that part of St. Mary Ridge between Duck Lake and Divide Mountain as a remnant of the highest plain.

There is some indication that ice of the Wisconsin stage spilled over the sag now traversed by the automobile road between the higher part of St. Mary Ridge and Divide Mountain on the south, though it did not overtop the old drift to the north.

DRIFT ON MILK RIVER RIDGE

On the north side of the valley of the North Fork of Cut Bank Creek is another great ridge of Cretaceous shale and sandstone left from the erosion of the high-level plain. This is known as Milk River Ridge from the fact that tributaries of the Milk River head on its north slope. Down the great trough between Cut Bank Creek and Milk River Ridge the Cut Bank Glacier extended at Wisconsin stage of glaciation, attaining a length of 12 miles east of the mountain front. A climb of 1,600 feet from the valley bottom to the point where Milk River Ridge joins the mountain front shows that the deposits are much disturbed by landslides, but it looks as if the ice emerging from the mountain valley extended this high up on the slopes. Overtopping the western end of Milk River Ridge, the glacier appears to have spilled across the crest, extending a small lobe about 2 miles northeastward down the slope on the north. Perhaps this was assisted somewhat by ice descending from a big cirque in the east slope of the mountain. Two well-formed lateral moraines are seen curving northward through the east side of a sag in the crest of the ridge. Across this sag, on the high flat top, which here stands 6,100 feet above the sea, it is evident that the last ice just overtopped the north slope at the west end of this part of the ridge and left there a small marginal ridge of drift. This may be traced eastward about three-quarters of a mile on the top of the ridge; it then drops to a lower level and lies along the slope 100 feet or so below the top. On the high flat part of the top of the eminence, beneath and beyond the little marginal ridge, is a deposit of coarse gravelly drift, yellowed with age, in which no limestone was observed, although a massive bed of limestone is exposed in the mountain slope to the west, and derived fragments are plentiful in the later drift. This deposit does, however, contain striated pebbles. Its character and relations show that it is another remnant of the old high-level drift. At the east end of this mesa an abrupt slope drops down about 500 feet to a second sag in the crest 1¼ miles in width. This broad sag in the crest, which is crossed by the automobile road, afforded another spillway for the last Cut Bank Glacier, and through this a tongue of ice extended northward a distance of 3 miles into the Milk River Basin, spreading out on the lower ground as a lobe over 2 miles in width. This small lobe is designated the Milk River Glacier by Calhoun.[65]

East of this second sag a climb of about 350 feet up a steep slope reaches the top of the main part of Milk River Ridge. From the high west end can be seen an extensive and remarkably smooth plateau, sloping down toward the northeast. In the first 1½ miles the surface declines 300 feet; beyond this there is a fairly uniform slope of nearly 80 feet to the mile for 5½ miles, the farthest distance to which the tract was traversed by the writer. Farther east deepening ravines cut the plateau into digitate flat-topped ridges, and these in turn give place to successively lower separated buttes.

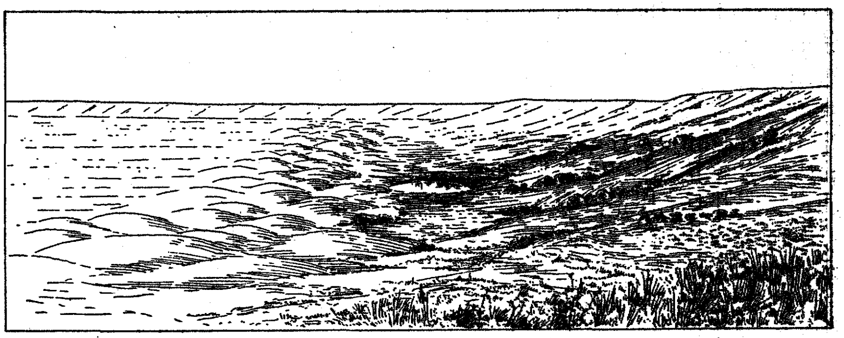


FIGURE 1.—View looking eastward from a point about 4 miles north of Duck Lake, Mont. Shows relations of the terminal moraine of the St. Mary Glacier, of the Wisconsin stage of glaciation, to the north slope of the Hudson Bay divide, on whose top lies pre-Wisconsin glacial drift (in the background and to the right). From a photograph

The drift of the Wisconsin stage extends nearly to the top of the head of the high-level plain, reaching an altitude of 5,800 feet and piling up in sharp knolls and ridges. This drift, however, overlaps little if any of the upper plain. Eastward from this point the margin of the later drift gradually descends the eroded south slope until in about 5 miles it lies 300 feet or more below the upland at the point where the marginal moraine of the valley glacier swings off to the south across the valley plain.

Underlying this extensive high-level plain is a yellowish to brownish oxidized gravelly deposit, consisting principally of quartzite with much green and red argillite, diorite, and some limestone. The stones are subangular to rounded. Numerous boulders 1 to 1½ feet in diameter are found 2 to 3 miles from the head

[65] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, p. 20, 1906.

of this plain and 8 to 10 miles from the mountains, the source of all the material. That exposed in a ravine in the NE. 1/4 sec. 12, T. 33 N., R. 13 W., consisted of clay, pebbles, and boulders mixed as in glacial till. In the SE. 1/4 sec. 12, 100 feet of unassorted material was found, and in the NW. 1/4 sec. 6, T. 33 N., R. 12 W., a thickness of 150 feet was observed. Here and elsewhere glaciated pebbles were found, though these are nowhere abundant and consist mostly of the green quartzitic argillite. Striated erratics were found in the sides of the valley of Arnold Creek as far out on this plain as the traverse was extended.

DRIFT ON CUT BANK RIDGE

Between the South and North Forks of Cut Bank Creek is a ridge of Cretaceous shale, whose crest 1 mile from the mountain front is 6,300 feet above the sea. An observer standing on this crest looks down 1,000 feet to the stream on the south and 1,200 feet to the bottom of the valley on the north. Both slopes are steep, that on the north being particularly precipitous. Shale is exposed within 100 feet of the top near the west end of the highest part of the crest. Here there is an abrupt drop in the crest line, and from this point to the mountain the crest is narrow, lower, and composed of shale. The highest part of the ridge is capped with till and gravelly drift, which is exposed at several points in fresh scarps due to landslides. The material has the same lithologic composition as that on Two Medicine Ridge, and many of the green argillite fragments show glacial striations. (See pl. 15 *B*.) This rock is very dense, fine grained, and so difficultly soluble as scarcely to be etched at all, even after very long exposure to the weather. Some of the limestone blocks are 6 to 8 feet in length. The top of this ridge is broad, smooth, and gently sloping. The north slope is heavily timbered, and there has been much slumping of the drift on the underlying shale, so that the upper limit reached by the North Fork Glacier during the later extension of the ice has not been accurately determined. The conditions on the opposite side of the valley indicate that the surface of the later ice was at least 200 feet below the top of this ridge.

Between 4 and 5 miles east of the mountain the crest drops 300 or 400 feet to a sag. Through this sag, which is traversed by the automobile road, the ice of the North Fork Glacier of the Wisconsin stage appears to have extended nearly or quite to contact with that of the South Fork Glacier. Beyond the sag the crest rises again 200 to 300 feet, maintains its height for about a mile, and once more drops to a much lower level, over which the later ice spread morainal deposits. Two miles farther southeast the ridge, here consisting of sandstone, rises again above the later drift and extends thence eastward with even, flat top for 2 miles, to the point where it is cut by the post-glacial gorge of the South Fork of Cut Bank Creek. East of this creek the ridge continues toward Browning but is still lower and was overridden by the later ice. Both the isolated mesalike parts of the ridge are capped with coarse gravel, largely quartzite, evidently to be correlated with the drift farther west and on Two Medicine Ridge, although here no till and no striated pebbles were observed.

DRIFT ON TWO MEDICINE RIDGE

Issuing from the mountains about 7 miles northwest of Glacier Park station, the Two Medicine River swings southeastward and traverses the plain in a sharply cut, trenchlike valley. The Lower Two Medicine Lake lies about 600 to 800 feet below the level of the rolling drift-covered plain on the east. The upland north of the railway and along and east of the automobile road has a well-marked though mildly developed sag and swell morainal topography and is set with numerous little ponds. This marks the marginal moraine of the Two Medicine Glacier of the Wisconsin stage. (See pls. 1 and 37.) In that part where the old automobile road runs eastward for a mile or more, near the margin of this morainal belt, in sec. 25, T. 32 N., R. 13 W., and sec. 30, T. 32 N., R. 12 W., before dropping down the slope to the north, the moraine extends nearly to the highest part of the upland, but farther east the margin of the moraine is a fairly definite line near the foot of the south slope of a long flat-topped sandstone ridge, part of Two Medicine Ridge. To the east the later ice extended through the gap in the sandstone ridge which is traversed by the Great Northern Railway and spread over the lower land toward Browning. Through a length of 3½ miles north and west of the railway the ridge was not surmounted by the later ice sheet. Above the abrupt slope the top is flat except where it is cut by a ravine that partly divides the ridge. It rises gradually westward from 5,300 to 5,700 feet above the sea in the part traversed by the old automobile road. This plateau surface, which is a remnant of No. 1 bench, is beveled across the edges of the Cretaceous sandstone, which at one point noted has a dip of 42° SW. The only constituents of the later drift not found on this part of the higher ridge are limestone and a quartzite conglomerate containing pebbles of black chert, which occurs principally in the drift somewhat farther south and is from ledges exposed in Marias (or Roosevelt) Pass and provisionally referred by T. W. Stanton to the Lower Cretaceous (Kootenai? formation). Fragments of this conglomerate may not have been deposited on this upland tract, and the limestone if deposited may have been removed by solution.

The material capping the ridge where the old automobile road starts down the north slope and also in cuts in the upper part of the slope consists of coarse gravel and boulders, with stones ranging in size from a fraction of an inch to 3 feet. The stones are mostly subangular, being notably less rounded than the waterworn gravel on the Cypress Hills and the Flaxville Plain or the high benches along the Yellowstone. The constituents are mostly red and green fine-grained siliceous argillite, some white to buff quartzite and some badly decayed diorite. No limestone was found. Search revealed that some of the argillite pebbles are glacially striated. All the drift exposed here has been considerably weathered.

For a mile or more northwest of the junction of the old automobile road and the old wagon road, north of the bench mark 5,649, the moraine of the later drift overtops the ridge. Farther west the sandstone ridge rises above the later drift plain, increasing rapidly in height, until it stands as a flat-topped mesa with an altitude of 6,200 feet, or nearly 400 feet above the margin of the later drift and about 1,350 feet above the lake. Here there is a deposit of the same material, and among the pebbles a few of limestone were noted. This high tract has a length of about half a mile. Beyond this there is a sharp drop in the crest of 100 feet or more, and west of the sag the crest rises again until the 6,200-foot level is attained. On this top were found coarse gravel and boulders of the same character as noted farther east. Many of the stones, however, are much larger, some boulders being 8 feet in length. The deposit seems to thicken toward the Two Medicine Valley, and at the southwest extremity of the half-mile mesa top a scarp, due to slumping of the underlying Cretaceous material, exposes 150 feet or more of typical glacial till near the new automobile road, which was completed in 1929. (See pl. 16 *A*.) A large part of the deposit is cemented by calcium carbonate to hard tillite.

This stood with nearly vertical face and with towers 25 to 30 feet in height, practically unchanged in the interval between the first examination in 1911 and a reexamination in 1921. Some of the stones are well rounded, but a large part of the pebbles and boulders are subangular, faceted, and distinctly striated. The material is wholly derived from the mountains, being of the same lithologic character as the gravel found on the ridge farther east. Limestone is rare among the stones scattered over the mesa top and also in the upper 25 to 30 feet of the 200-foot section. Farther down the slope, however, it becomes more plentiful and shows less effects of weathering. It is probable that the calcareous cement of the tillite was derived from solution of the limestone material in the upper part of the deposit. This exposure faces the mountain slope at a distance of over a mile. Between the two the ridge has been lowered and narrowed by erosion and slumping. It is here that the new automobile road crosses the crest of the ridge. This lower part is densely timbered and was not examined. From this narrowed divide the valley between the high mesa and the much higher mountain slope deepens rapidly northward to 1,000 feet below the top of the mesa.

The composition of the deposits on the several ridges described above, their topographic situations relative to the mountains, to the present drainage lines, and to the deposits made by the glaciers of the Wisconsin stage, the modification by weathering, and the cementation to heavy beds of tillite all indicate that these glacial deposits are of early Pleistocene age.

Two Medicine Ridge is the most southerly of the remnants of the high benches bordering the front range of the Rocky Mountains on which pre-Wisconsin glacial drift has been found. For 30 miles to the southeast no traces of the high benches are found. South of Badger Creek there are many remnants of No. 1 and No. 2 benches, as described on pages 15–16, but on none of these has any evidence of glacial action been found outside of or above the limits of the drift of the later mountain glaciers. Either the pre-Wisconsin glaciers south of Marias Pass did not extend as far beyond the mountain front as the present high bench remnants, or the evidence of glaciation has been obliterated by subsequent weathering. The pebbles on these high benches consist principally of limestone, and their surfaces have been etched and roughened by solution and are in large part coated with calcium carbonate. The dense greenish and reddish siliceous argillite which is so plentiful in the Glacier National Park region and which is best adapted of all the rocks composing the pebbles or boulders at or near the surface to retain glacial striation is relatively scarce on the high benches south of the Two Medicine River. The relative altitudes and the topographic relations of No. 1 and No. 2 benches north and south of the Two Medicine River are the same, however, so that it would seem that their age relations would also be similar.

The question arises, Was there more than one stage of mountain glaciation before No. 2 bench was deeply dissected? Unfortunately, the evidence in hand on this point is not decisive. The most easterly points at which striated pebbles have been found in gravel on remnants of No. 1 bench are (1) about 4 miles east of Duck Lake, in sec. 20, T. 36 N., R. 12 W., from which a narrow strip of this bench persists for nearly 15 miles farther to the northeast and at its end is 100 to 250 feet above the Milk River; (2) 6 to 7 miles northeast of Horse Lake, in sec. 12, T. 35 N., R. 12 W.; and (3) 8 miles east of Horse Lake, in sec. 33, T. 35 N., R. 11 W. These narrow remnants of No. 1 bench are capped by gravel, composed mostly of quartzite and red and green siliceous argillite, with some diorite, all from the mountains. The tops and slopes of the ridges are grassed over, and it is only at intervals around the margins of the tops that as much as 1 to 3 feet of the gravel, which is probably thin, is exposed. The stones range from small pebbles to boulders 1½ feet in length and are partly subangular and partly well rounded. Those most commonly showing glacial striae are of the dense siliceous greenish argillite. (See pl. 15.) Some of those on No. 1 bench have been found 20 miles east of the mountain front. The gravel is not well exposed, and it was not determined whether or not there is glacial till this far out on No. 1 bench. If the material is glaciofluvial (outwash) gravel, the ice may not have extended this far east, but the gravel must have been deposited before erosion cut down from No. 1 to No. 2 bench, for No. 1 is 100 feet or more above No. 2 bench, and where the two are found on the same ridge they are generally separated by a short, steep slope. Some of the remnants are separated by intervals of 8 to 12 miles from the tracts that carry the old high-level glacial till with which they are to be correlated.

If it is supposed that the first advance of the mountain glaciers did not occur until after erosion had lowered the general surface of the plain to the second bench level, the only way the striated pebbles could reach the outlying remnants of No. 1 bench would be for the ice to have extended eastward onto these remnants—that is, 20 miles out from the mountain front. If the advance occurred before the dissection of No. 1 bench the striated pebbles may have been washed out by streams flowing from the melting ice fronts. In that event it is possible that a second advance of the ice occurred after the dissection of No. 1 bench and after No. 2 bench had been developed by planation over areas many miles in extent.

The best-preserved remnant of No. 2 bench is on Milk River Ridge north of Cut Bank Creek. A small remnant of No. 1 bench at more than 5,900 feet above sea level is preserved above the abrupt slope on the east side of the notch crossed by the automobile road. This is slightly above the upper limit of the later ice that spilled through the notch. Within a mile and a half the smooth top of the ridge drops 300 feet and then flattens out as No. 2 bench, nearly 4 miles in maximum width, and continues more than 12 miles to the northeastward, though palmately dissected by several sharp coulees. As shown on Plate 1, there are numerous remnants of No. 2 bench in the Blackfeet Indian Reservation (Browning and Blackfoot quadrangles). All of these are adjacent to the headwater branches of the Milk River.

The relations indicate that it was probably not until after the melting of the early mountain glaciers from the No. 2 plain that the waters of upper St. Mary, Red Eagle, Boulder, and Kennedy Creek Valleys were diverted toward the north. Before this diversion most if not all of this drainage probably went eastward to the Milk River, and it was the work of planation along the several branches that cut away all but a few narrow interstream remnants of No. 1 bench and developed No. 2 bench.

Glacially striated pebbles have been found in the gravel on all those remnants of No. 2 bench which have been examined north of the Two Medicine River and as far as 20 miles east of the mountain front. (See pl. 15 *A*.) Many of the stones are 10 to 12 inches long, and some 1 to 2 feet. No unsorted till was found on No. 2 bench. This bench is 200 to 300 feet above the headwater branches of the Milk River and 500 to 600 feet above Greasewood and Cut Bank Creeks. Either there was an extension of the mountain glaciers after No. 2 bench was developed or the striated pebbles have been let down onto it by erosion from No. 1 bench in the process of dissection and planation.

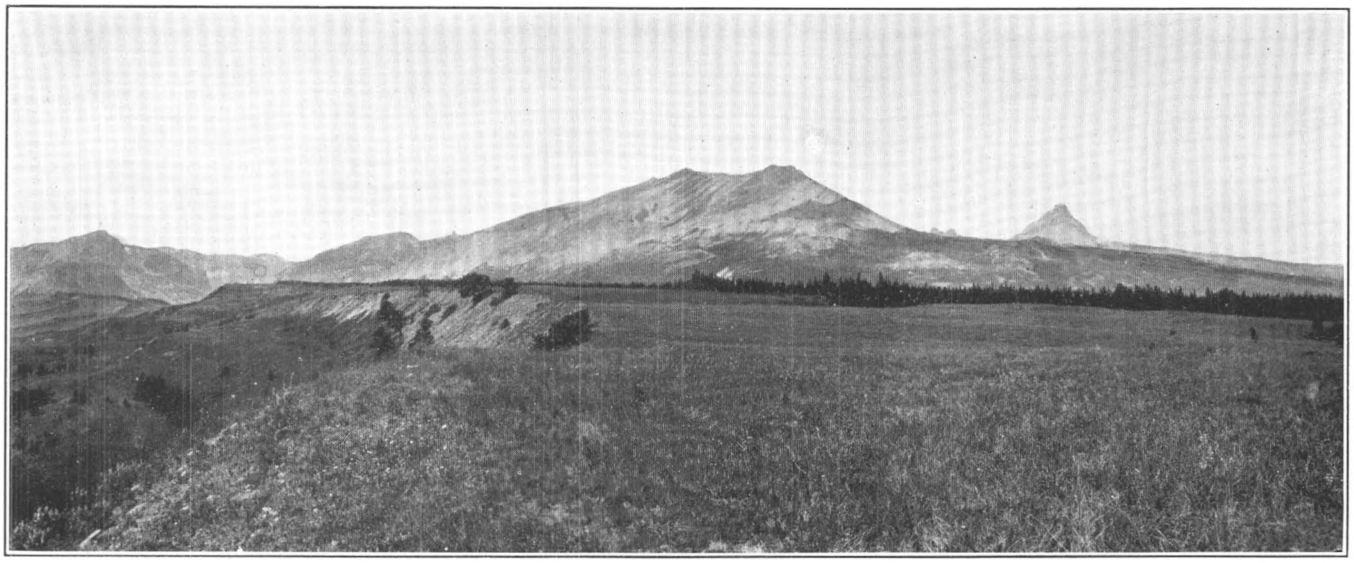
No. 2 bench is clearly of Pleistocene age, and it includes the remnants of the upper levels of the second set of benches farther south and east. So far as known, however, none of the gravel on these remnants south of the Two Medicine River includes glacially striated material.

POSSIBLE PRE-WISCONSIN GLACIAL DEPOSITS

CASTLE AND BEARTOOTH MOUNTAINS, MONT.

Although there are no positive evidences of early Pleistocene mountain glaciation south of the Two Medicine River known to the writer, there are in a few places features which, though requiring further investigation, suggest the extension of the mountain ice before the high benches were greatly dissected. One of the most definite of these is near the head of the Musselshell River, at the south side of the Castle Mountains. Between the Chicago, Milwaukee, St. Paul & Pacific Railway west of Lennep and Alabaugh Creek on the north is a ridge nearly 6 miles long whose top is 200 to 400 feet above the creek. The west end of this ridge joins the foot of the mountains near Castle, about 6,200 feet above sea level. It appears to be a remnant of one of the highest benches, such as occur farther east in the Musselshell Valley. The top of the ridge, which was examined by the writer in 1922 and 1923, is thickly strewn with a great number of glacial boulders, mostly porphyry, which range in size from a foot or less to 5 feet in diameter. Weed[66] described this deposit as glacial drift. He also described a newer terminal moraine a short distance above the town of Castle, which "closes in the upper

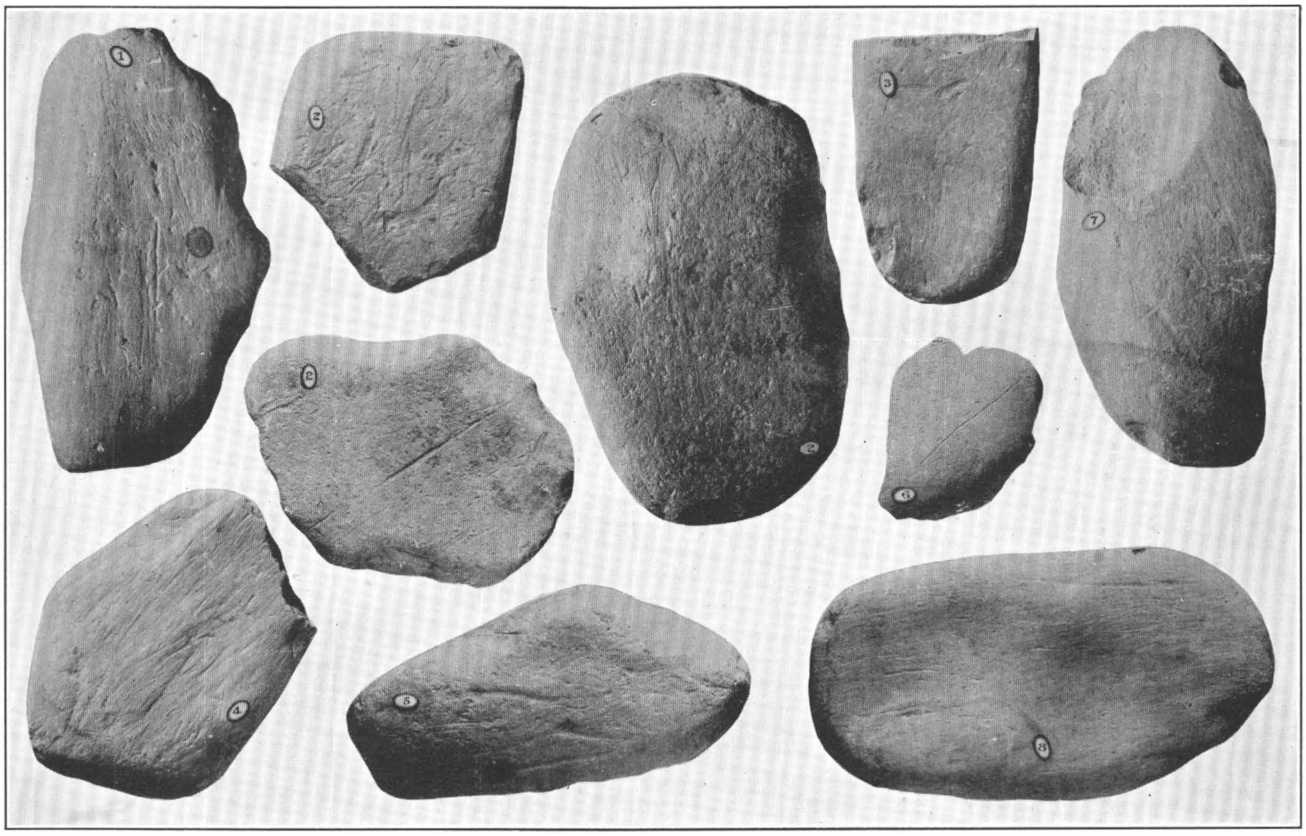
[66] Weed, W. H., Geology of the Castle Mountain mining district, Mont.: U. S. Geol. Survey Bull. 139, pp. 144–145, 1896; U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 56), pp. 3, 7, 1899.



A. FLAT TOP OF SWIFTCURRENT RIDGE
Looking northwest to Yellow Mountain; Chief Mountain at the right.

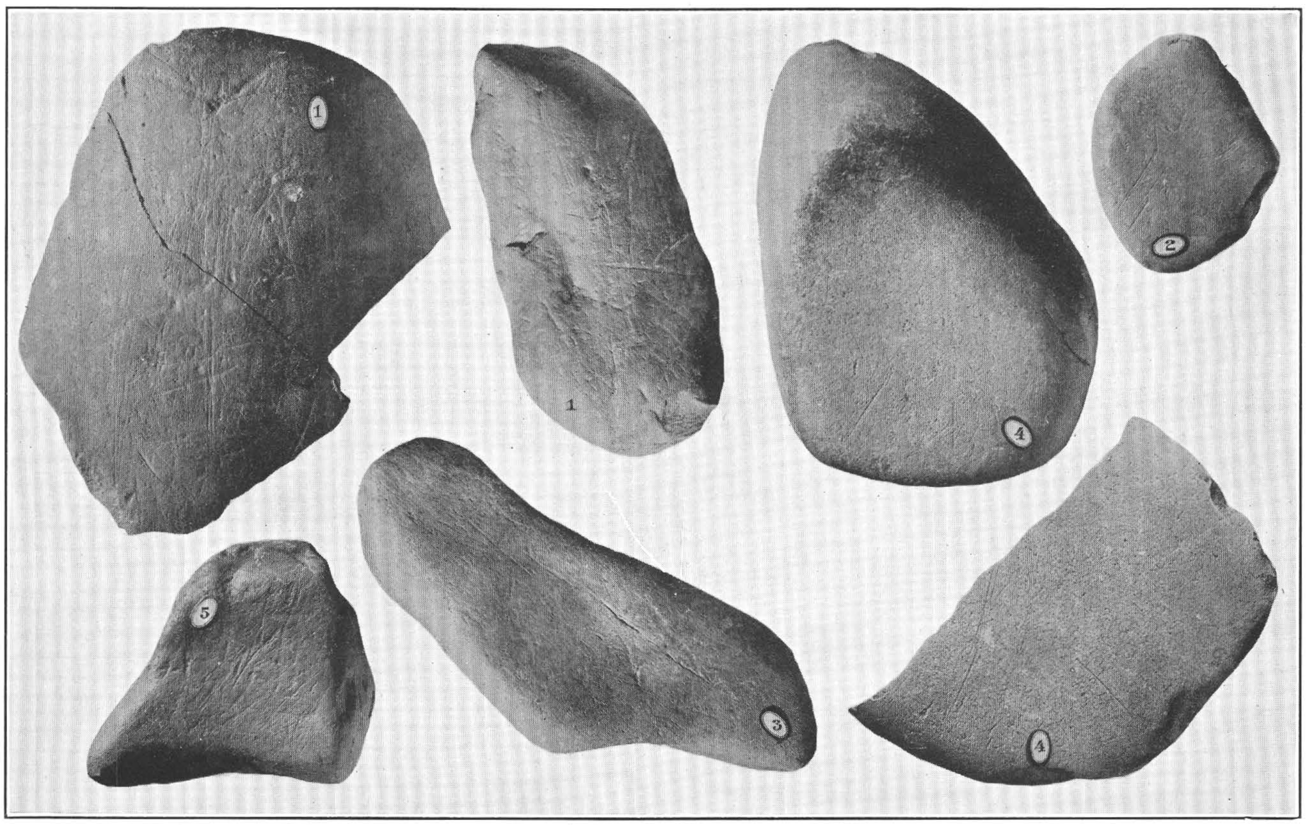
B. KENNEDY RIDGE, 5 MILES EAST OF CHIEF MOUNTAIN
Photograph by Bailey Willis.

PRE-WISCONSIN DRIFT OF ROCKY MOUNTAIN GLACIERS, GLACIER NATIONAL PARK, MONT., ON REMNANTS OF THE FLAXVILLE PLAIN (HIGHEST OR No. 1 BENCH)



A. ON REMNANTS OF THE HIGHEST (No. 1) BENCH (FLAXVILLE PLAIN) AND LOWER (No. 2) BENCH

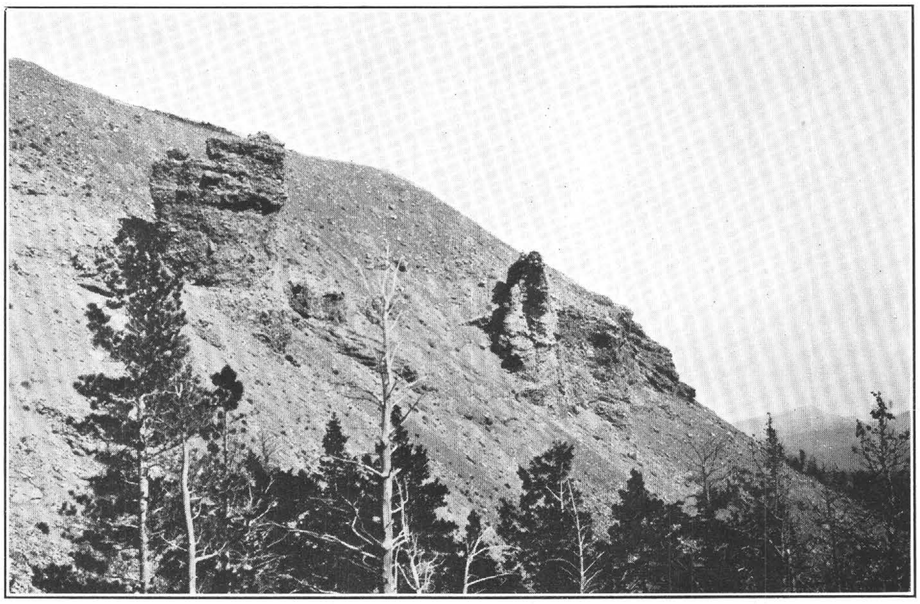
1 to 5 from No. 1 bench; 6 to 8 from No. 2 bench. Locations: 1, Makowan Butte, 5 miles north of international boundary; 2, Kennedy Ridge; 3, ridge between Dry Fork and Livermore Creek, 5 miles southeast of Duck Lake; 4, Two Medicine Ridge north of the lower lake; 5, east slope of St. Mary Ridge at head of Livermore Creek; 6, ridge 3 miles southeast of Duck Lake; 7, ridge north of Petersen Coulee; 8, Milk River Ridge 1 mile south of Horse Lake.



B. ON REMNANTS OF THE HIGHEST (No. 1) BENCH

Locations: 1, Hudson Bay Divide, 3 to 4 miles north of Duck Lake; 2, ridge 4 miles east of Duck Lake; 3, ridge 9 miles southeast of Duck Lake; 4, ridge 8 miles east of Horse Lake; 5, Cutbank Ridge.

GLACIATED PEBBLES FROM PRE-WISCONSIN DRIFT OF ROCKY MOUNTAIN GLACIERS IN SOUTHWESTERN ALBERTA AND BLACKFEET INDIAN RESERVATION, MONT.

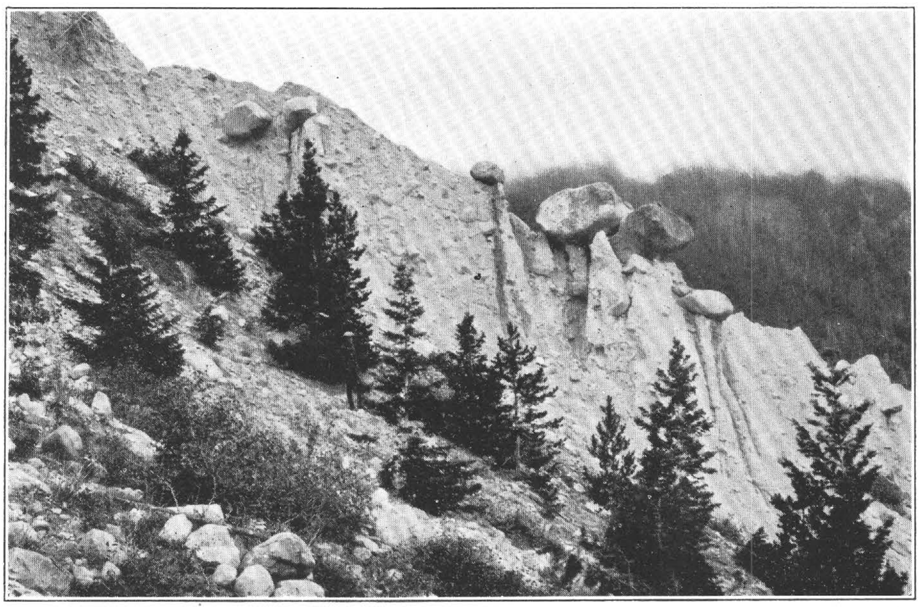


A. PRE-WISCONSIN GLACIAL DRIFT, LARGELY CEMENTED TO TILLITE
Exposed at west end of highest (No. 1) bench, north of Lower Two Medicine Lake, Glacier National Park, Mont.

B. BOULDERY DEPOSIT ON HIGHEST (No. 1) BENCH EAST OF ROSCOE, MONT.

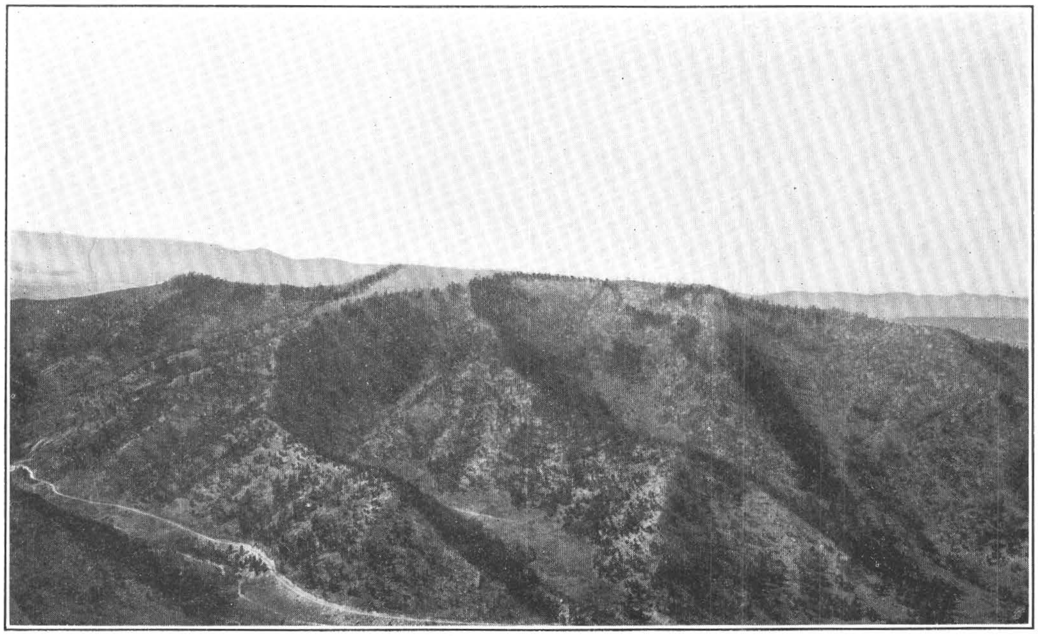
PRE-WISCONSIN DRIFT OF ROCKY MOUNTAIN GLACIERS

A. HANGING VALLEY OF WOODBINE CREEK
High-level glacial till (pre-Wisconsin) at left (light-colored), 800 to 1,300 feet above the river.



B. NEAR VIEW OF PART OF HIGH-LEVEL TILL SHOWN IN *A*
Mountain top shrouded in mist

STILLWATER CANYON, BEARTOOTH MOUNTAINS, MONT.



A. NORTH RIDGE AT EAST FRONT OF MOUNTAINS WEST OF BUFFALO, WYO.

Probably a remnant of the Flaxville Plain (No. 1 bench), capped with a bouldery deposit, probably pre-Wisconsin glacial drift.

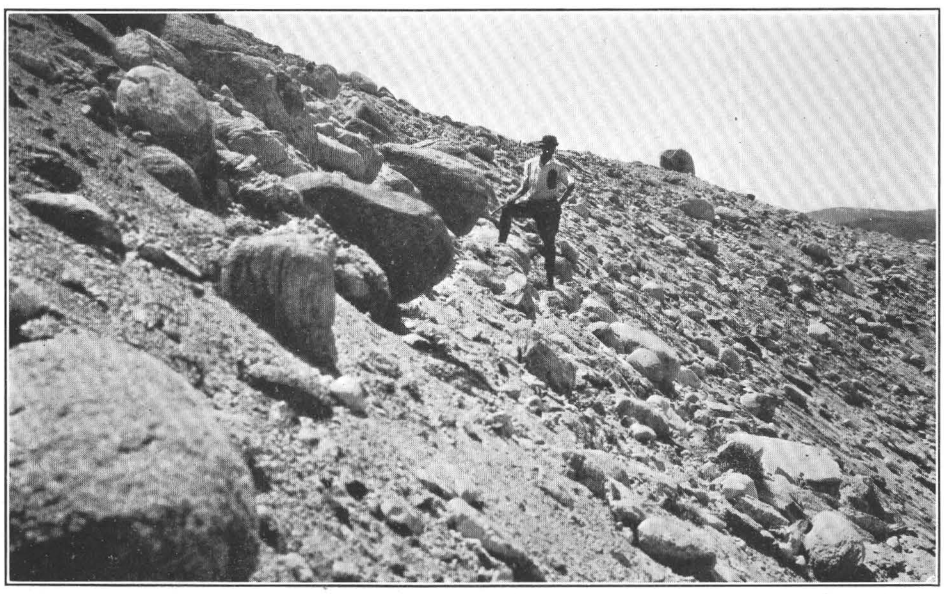
B. ANCIENT HIGH-LEVEL PLIOCENE OR PLEISTOCENE VALLEY

View from top of North Ridge looking west. In the bottom of the valley is cut the gulch traversed by the automobile road (in middle) and Clear Creek Canyon (at left). Subsummit plateau at left and right; central granitic peaks in background.

BIG HORN MOUNTAINS, WYO.

A. BOULDERY CREST OF MONCRIEF RIDGE, 13 MILES SOUTH OF SHERIDAN

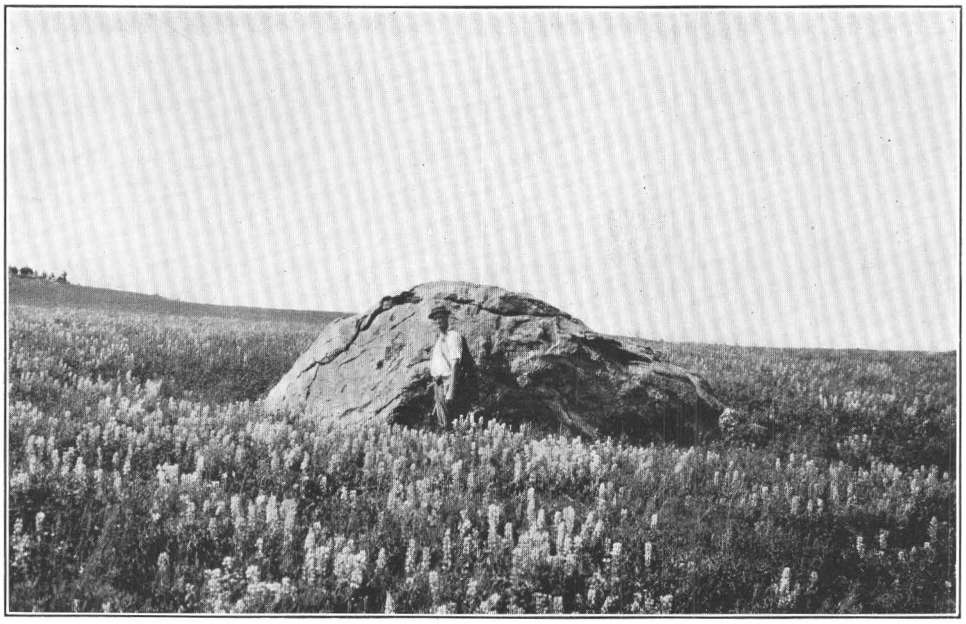
Near east front of mountains. Many of the boulders are 5 to 15 feet in diameter.



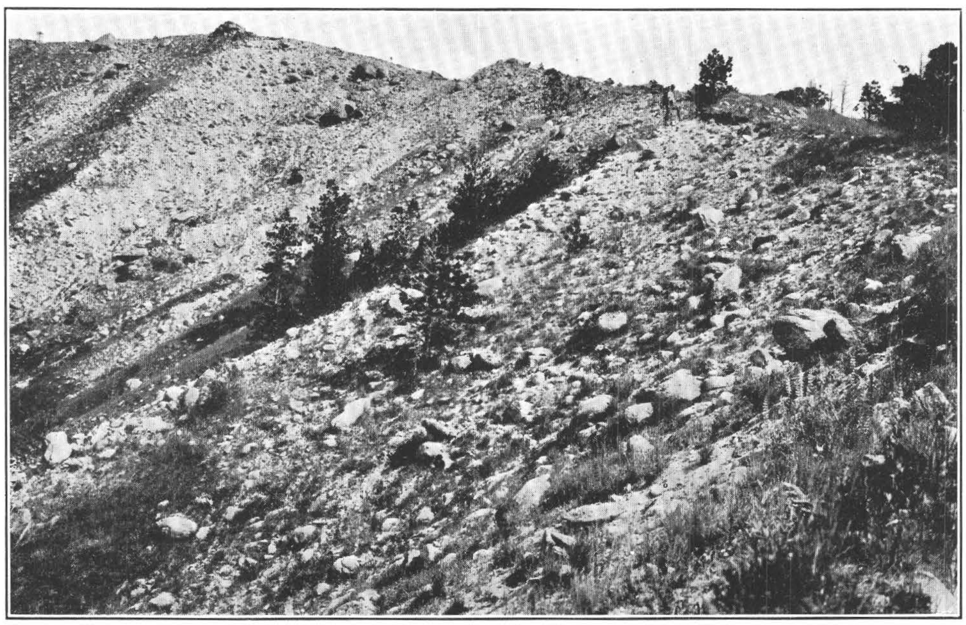
B. HIGH-LEVEL BOULDER DEPOSIT CAPPING MONCRIEF RIDGE

Boulders mostly granite and deeply weathered.

BIG HORN MOUNTAINS, WYO.

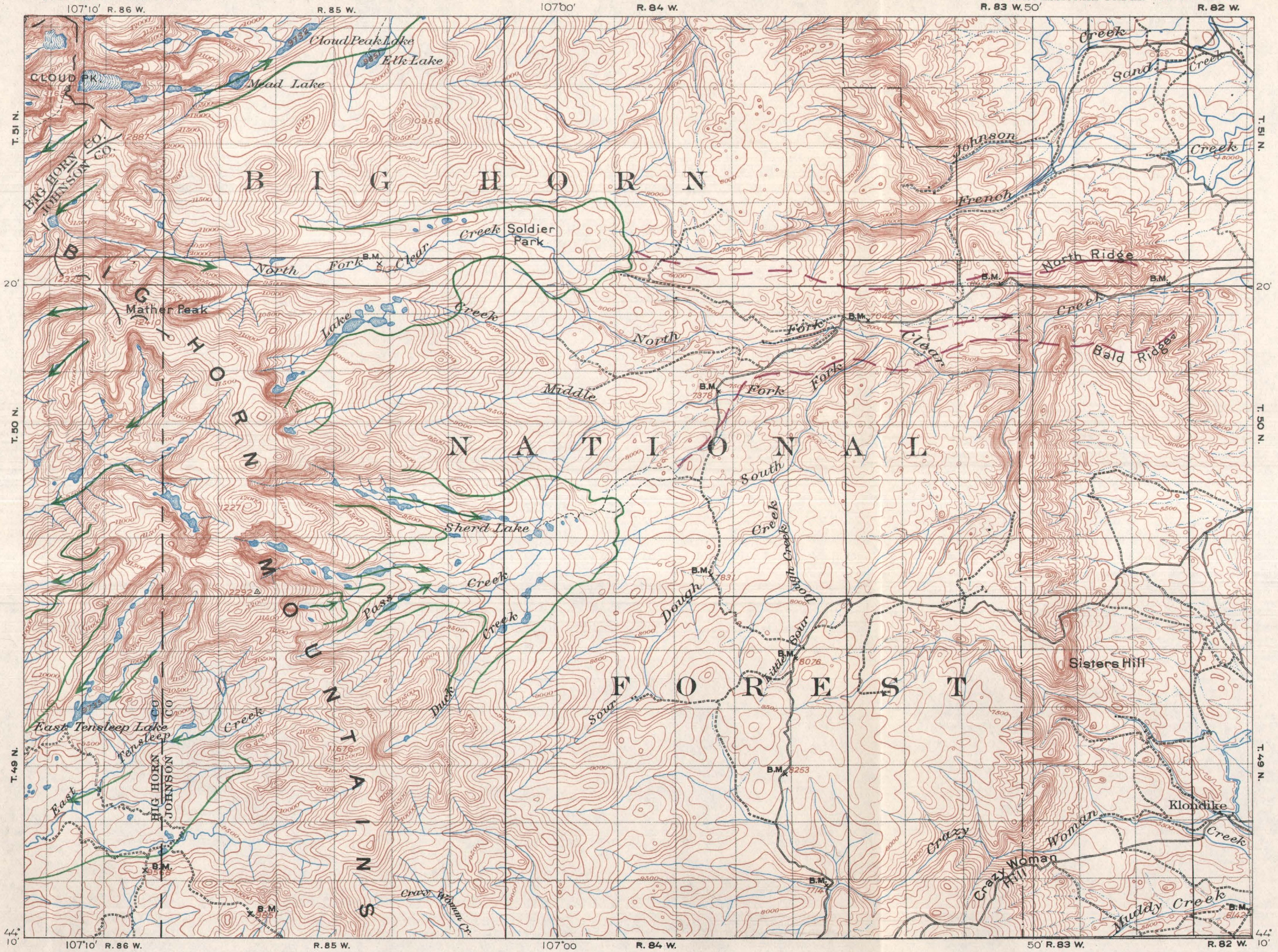


A. GRANITE BOULDER ON TOP OF BALD RIDGE, WEST OF BUFFALO
Boulder is 20 feet long.



B. HIGH-LEVEL BOULDER DEPOSIT CAPPING BALD RIDGE
Near the east front of the mountains.

BIG HORN MOUNTAINS, WYO.



Base from U. S. Geological Survey maps of Cloud Peak and Fort McKinney quadrangles. Surveyed in 1897–1900

TOPOGRAPHIC MAP OF A PART OF THE BIG HORN MOUNTAINS WEST OF BUFFALO, WYOMING

Scale $\frac{1}{125000}$

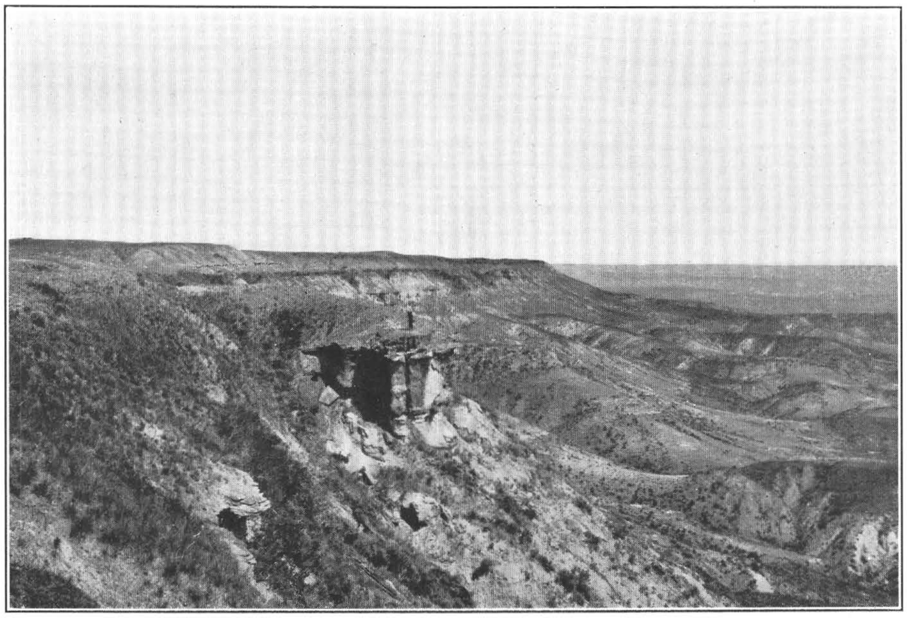
1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

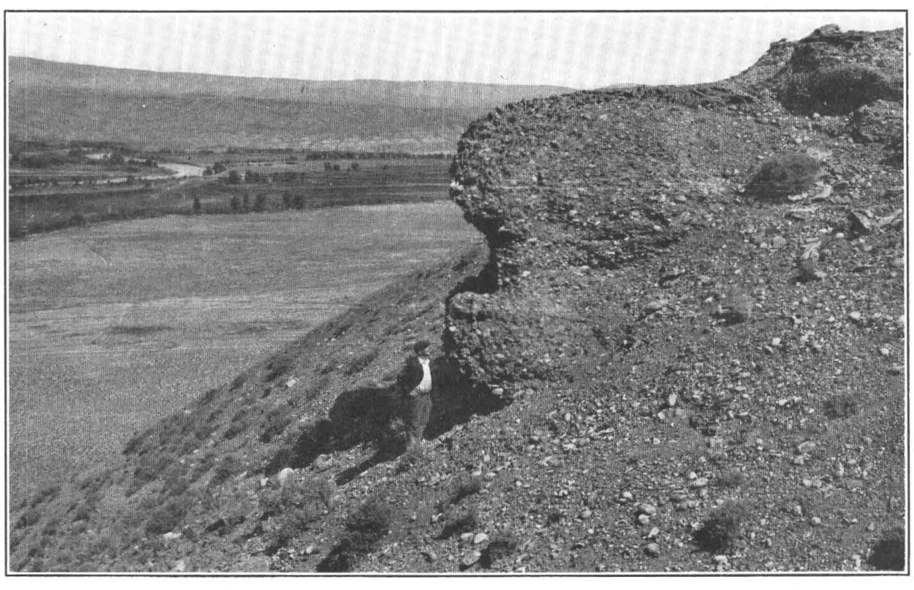
Datum is mean sea level.

Green lines show limits of glaciers of the Wisconsin stage. After E. S. Bastin and Eliot Blackwelder. Purple dashed lines show possible limits of Clear Creek glacier at an early Pleistocene stage of glaciation. By Wm. C. Alden.



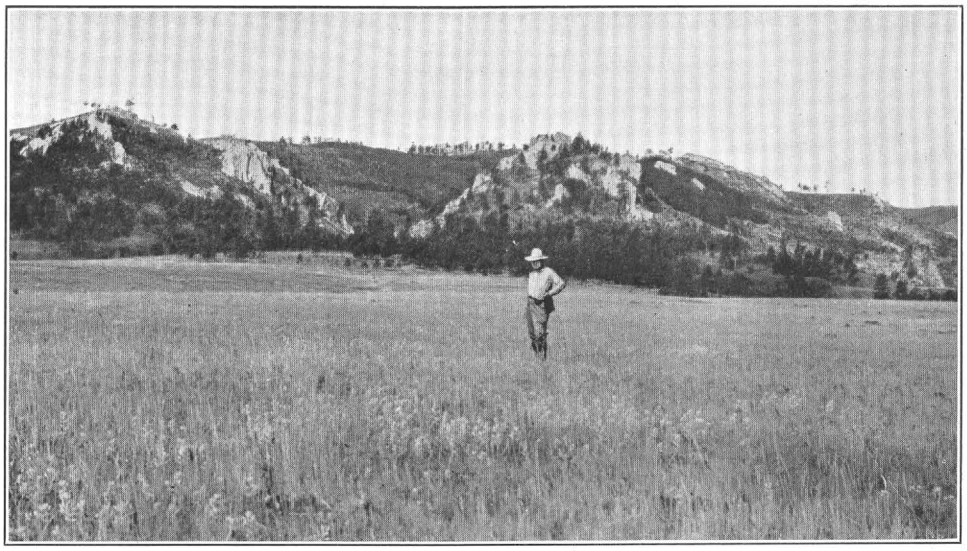
A. No. 2 BENCH 17 MILES NORTHEAST OF MALTA, MONT.

View near Lovejoy road, on west side of Milk River Valley. Shows Judith River sandstone underlain by Claggett shale and overlain by 10 feet of nonglacial quartzite gravel of No. 2 bench (Pleistocene), 350 to 400 feet above the river. Upon this gravel is 30 feet of till of the Keewatin ice sheet.



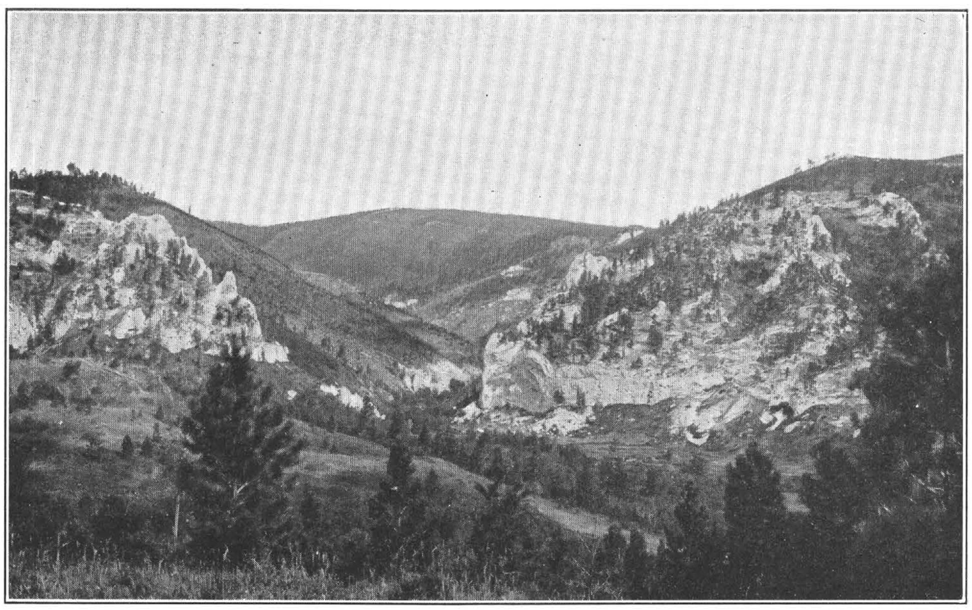
B. PLEISTOCENE CONGLOMERATE ON CLARK FORK OF THE YELLOWSTONE RIVER

Capping a remnant of No. 2 bench 200 feet above the river, near the J. F. Allen ranch, 2 miles north of the Montana-Wyoming State line.



A. No. 2 BENCH HEADING AT A GREAT NOTCH IN THE WALL OF UPTURNED PALEOZOIC LIMESTONE

View south of Beaver Creek. The highest (No. 1) bench, corresponding to the Flaxville Plain, before its destruction headed at the top of the limestone wall, about 300 feet higher than No. 2 bench.



B. BEAVER CREEK CANYON AS SEEN FROM No. 2 BENCH, 350 TO 400 FEET ABOVE THE PRESENT STREAM

LITTLE ROCKY MOUNTAINS, MONT.

mountain valley," and states that the recent aspect of this moraine

is in marked contrast to the appearance of the adjacent boulder moraines previously noted. It fills the drainage valley and marks the front of an area in which the glacial rock polishing and other evidences of glaciation are remarkably fresh and well preserved. Both the contrast in appearance and the relative position of this moraine, with the morainal remains found on the adjacent slopes, show that they are of very different age.

After noting similar relations on Fourmile and Willow Creeks east of White Sulphur Springs, Weed states: "These facts clearly indicate two periods of glaciation, one of which is much older than the other, the later being of much less severity."

Another deposit of glacial drift which attracted the attention of the present writer, because of its anomalous position, was seen in 1921 and again in 1924 near the old Wood ranch (or Beartooth ranch) in Stillwater Canyon, in T. 5 S., R. 15 E., 8 miles above the Nye Bridge. Just opposite the ranch there is a beautiful waterfall where Woodbine Creek plunges down 1,000 feet or more in a series of cascades from the mouth of a hanging valley that notches the east wall of the canyon. (See pl. 17 *A*.) Just north of the falls and 800 to 1,300 feet above the valley bottom a great mass of glacial till several hundred feet in height is banked below the lip of the hanging valley. The bare gray face of the till surrounded by woods is conspicuous as seen from below. (See pl. 17 *B*.) Its grayish matrix is thickly set with pebbles and boulders as much as 5 feet in length, some of them balanced on knife-edge ridges of the semi-indurated till. The stones are largely coarse-grained granite, mostly gray, some pink, together with other igneous rocks. The top of the deposit is about 6,300 feet above sea level (barometric), which is not far from the level at which No. 1 bench probably reached the mountain front at the mouth of the canyon. This unusual occurrence of so great a mass of till on a canyon wall and so high above its bottom strongly suggests that it may be a remnant left by a pre-Wisconsin glacier which extended down the valley and possibly out onto No. 1 or No. 2 terrace at the mountain front.

There are some other indications of early glaciation farther southeast near the mountain front. The occurrence of coarse bouldery material resembling glacial till on the highest bench 3 miles east of Roscoe, at an altitude of 5,400 feet, 400 to 500 feet above the adjacent creeks, is noted above (p. 26; see also pl. 16 *B*).

This deposit is about 8 miles northeast of the mouth of the canyon of East Rosebud Creek. At several places beside the road between Luther and Red Lodge, 2 to 4 miles from the mountain front, boulders of granite and limestone 3 to 5 feet long were seen in positions to which they may have been let down by the erosion of a high bench on which they had been left by glaciers.

For miles east of the terminal moraine near the mouth of Clark Fork Canyon in northern Wyoming the broad, flat gravelly terrace north of the river is strewn with granite boulders 1 to 8 feet or more in diameter. But for the boulders the gravelly terrace might be taken for an outwash plain. It is, however, very unusual, so far as the writer's experience goes, to find any such number of large boulders so far distant from a terminal moraine. That these boulders may have been let down from a higher bench by erosion is suggested by the fact that instead of being confined to the flat they are also sprinkled over the slopes of several small hills that rise above the surrounding plain, and also by the fact that boulders 5 feet in length were seen on remnants of No. 2 bench 12 miles down the valley, at points about 8 miles east of the mountain front. These facts give rise to the suggestion that a pre-Wisconsin glacier may have occupied the broad upper valley of Clark Fork and may have extended out beyond the mountain front onto either No. 1 or No. 2 bench at a time before the inner box canyon described on page 27 was eroded.

BOULDERY MESAS BORDERING THE BIG HORN MOUNTAINS, WYO.

Certain high-level bouldery deposits bordering the east flank of the Big Horn Mountains (pls. 18 and 19) which have been described by Darton were examined in 1923 and 1924 by the present writer. Under the heading "Tertiary system" Darton[67] gives a description of which the following is a part:

Among the most conspicuous features on the east slope of the mountains are the two high boulder ridges at the mouth of Clear Creek Canyon, west of Buffalo, and the similar ridge 6 miles south of Big Horn. The southern one of the pair west of Buffalo is known as Bald Ridge and the northern one as North Ridge. Their altitudes are 6,900 and 6,800 feet, respectively. The summits are nearly flat and but slightly lower than the limestone front ridge, from which they are separated by shallow saddles. The materials of these two ridges are granite boulders packed thickly in arkose sand and gravel and showing no evidence of stratification. The larger ones vary in size from 2 to 6 feet in diameter, but some are even larger. Most of them are rounded, and they have the appearance of being the delta deposit of a large stream. The majority of the rocks are deeply decomposed, and the boulders of medium and small size are completely rotted. Apparently there are no limestones or sandstones in the deposits, notwithstanding the proximity of ledges of these rocks to the west. The thickness was not ascertained satisfactorily, but it amounts to several hundred feet. * * * To the north small masses occur on many of the divides lying against or near the limestone front range, at altitudes of from 6,000 to 6,500 feet. Two of them are north of French and Johnson Creeks and three are on divides between branches of Piney

[67] Darton, N. H., Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, pp. 68–70, 1906; U. S. Geol. Survey Geol. Atlas, Cloud Peak-Fort McKinney folio (No. 142), p. 9, 1906.

Creek west of Kearney, being clearly remnants of a deposit which at one time extended all along the front range.

Moncrief Ridge, south of Big Horn, is similar in character to Bald and North Ridges. It has an altitude of about 6,300 feet and a flat top, separated from the adjoining limestone ridge by a saddle. It is a conspicuous feature in the view south from Sheridan as a high, glistening white terrace extending out from the mountain slope. The deposit consists of granite boulders, mostly rotted and mixed with arkose sand and pebbles. Some of the finer materials are in large lens-shaped masses exhibiting cross-bedding. There are fine exposures on the northwest end of the ridge, of which the principal features are shown in Plate 19 of the present paper. Many of the boulders are 4 feet in diameter, and some are larger. Granite and occasional masses of diabase and quartz appear to be the only materials. The thickness is at least 300 feet, and it may be much more, but the contacts are covered by talus. * * *

The age of the high-level boulder deposits is not ascertained. The deep decomposition of the boulders on Bald and North Ridges and other outliers shows that the deposits are much older than any of the morainal materials of the glaciers, and this may indicate either earliest Quaternary or late Tertiary age. The boulders show no signs of glaciation, but, owing to the decay, striae probably would not be preserved. Evidently the deposit originally extended over a wide area east of the mountains, as is shown by the widely scattered remnants, especially on Kingsbury Ridge, and since their deposition there has been extensive erosion to the present low level of the plains. Boulders of such large size as those in Bald Ridge and the other areas would have required streams of great power for their transportation, but it is possible that floe ice was a factor in their origin.

North and Bald Ridges, west of Buffalo, are situated like two remnants of a bisected alluvial fan opposite the mouth of a broad high-level valley and 16 to 20 miles distant from the mountain crest at the head of the basin. From the crest of the central granite ridge, which ranges in altitude from 10,500 to 12,887 feet, the eastern face slopes down in 6 to 10 miles to about 8,000 feet. Beyond this a rolling granite plateau extends eastward 6 or 7 miles to the rim formed by the worn-off edges of the upturned Paleozoic limestones at 7,000 to 7,600 feet. The ancient valley of Clear Creek cuts across this plateau with a depth of 500 or 600 feet and a maximum width of a mile or more. The bottom of this high-level valley is represented by the bouldery bench at an altitude of 6,800 to 7,000 feet, into which is cut the deep gulch now traversed by the Buffalo-Tensleep automobile road. (See pl. 18 *B*.) For 4 miles east of Hunters ranger station Clear Creek follows the course of this ancient valley and has cut its new gorge to depths of 200 to 300 feet along the south side; then swinging southward it flows around a ridge of granite for about 2 miles in a narrow canyon 600 to 800 feet in depth. Returning to the axial line of the old valley, it emerges from the mountains between North and Bald Ridges, which rise to heights of 1,000 to 1,300 feet. The top of Bald Ridge is nearly as high as the beveled edges of the upturned Paleozoic rocks at the edge of the plateau, and as shown on Plate 21 (see also topographic maps of Fort McKinney and Cloud Peak quadrangles), the tops of Bald and North Ridges are several hundred feet higher than the hanging bottom of the ancient Clear Creek Valley. There is no great mountain wall rising abrupt and high above the tops of North and Bald Ridges. They border a worn-down mountain top, yet granitic boulders 5 to 20 feet in diameter characterize the material composing these ridges. (See pl. 20.) The coarseness of this material in such a position suggests that the ridges are composed of glacial drift. The degree of decomposition which the granitic material has undergone indicates that the deposit is as old as early Pleistocene, if not older.

Owing to the sliding and rolling of the material down the steep slopes, Darton was unable to determine the actual thickness of the bouldery deposit or the altitude of the base on which it lies. It seems unlikely, however, that the rock on which its rests could have been cut down below the grade of the No. 1 benches at so early a time as Pliocene.

What appears to be a remnant of No. 1 bench is the flat sloping gravel-covered top of the ridge southeast of the Cross H ranch, about 6 miles south of Buffalo. The grade of the top of this mesa, if projected northwestward 6 miles with a normal increase in slope to about 150 feet to the mile, would pass under Bald Ridge at about 6,000 feet above sea level, and a further projection at 200 feet to the mile would extend it just under the bouldery filling of the bottom of the ancient high-level valley of Clear Creek, which forms the bench south of the automobile road. If this projected gradient is anywhere near correct, it appears that Bald and North Ridges consist of 700 or 800 feet of bouldery material piled on the upturned and truncated edges of the Triassic (?), Jurassic, and Cretaceous sandstones and shales. There is a small remnant of similar bouldery material about 100 feet thick on the crest of Kingsbury Ridge, about 5 miles south of Clear Creek and 3 miles from the mountain front, at 6,000 to 6,100 feet above sea level. No other remnants are preserved so far from the mountain front, and thus there is nothing to show how extensive the thick bouldery deposit originally was. It may be that Bald and North Ridges are the dissevered limbs of a great lobate terminal moraine which flanked and encircled the end of a vigorous glacier that early in Pleistocene time thrust its snout from the ancient mountain valley of Clear Creek 2 to 3 miles out onto the No. 1 bench or piedmont terrace. In this way the material may have been piled hundreds of feet higher than the bottom of the valley without having any such peripheral extent as would characterize so thick an alluvial cone. The apex of a cone with slopes so high as the crests of these ridges at points 2 miles from the mountain front would probably have been at least 500 or 600 feet higher, or nearly 7,500 feet above sea level. This altitude is nearly as high as the tops of the ridges on both sides of the ancient valley, where these crests are 2 miles apart and 1½ miles back from the mountain front. If all the factors are taken into consideration they do not appear to be favorable for the laying down of so thick a deposit of material so coarse by a stream on so low a base in front of so worn-down a mountain range at a time so recent as that of the completion of No. 1 terrace.

The writer is inclined to think that the deposit is either much older than the other terraces under consideration or else is, in part at least, an early Pleistocene glacial deposit. Pre-Wisconsin bouldery drift was mapped by Blackwelder as extending 2 to 3 miles beyond the limits of the drift of the Wisconsin stage of glaciation on the ridges on both sides of the Middle and North Forks of Clear Creek—that is, to positions within 6 miles of the points where Bald and North Ridges join the mountain front. Although bouldery material was not found on the upper slopes and crests farther east, a deposit of decomposing bouldery material caps the bench that represents the bottom of the ancient high-level valley. This, like the deposit composing Bald and North Ridges, was mapped by Darton as Tertiary (?), though he recognized the possibility of its being an early glacial deposit. No characteristic glacial striae, polish, or facets have been found on the pebbles and boulders, but so deeply weathered are the stones that any surficial markings must long ago have disappeared. The granites are crumbling or spalling off, and in places large feldspar crystals project 1 or 2 inches from the matrix before themselves falling out. There is thus little chance of proving that the deposit is of glacial origin.[68]

Further, as to the possibilities of Bald and North Ridges being early Pleistocene glacial moraines, it may be noted that if a glacier of the dimensions of that which occupied the North Fork Valley at the Wisconsin stage were projected 10 miles farther east, it would almost exactly fit the capacity of the old high-level valley of Clear Creek, and Bald and North Ridges would flank the outer 2 to 3 miles which projected onto the piedmont terrace beyond the mountain front. That there was so long a glacier here in early Pleistocene time, when the altitude of the mountains was probably about 1,000 feet lower than now, seems not at all improbable, in view of the fact that at that time the Keewatin ice sheet covered the plains but 300 miles to the east and extended 250 miles farther south in the Missouri Valley than it did at the Wisconsin stage of glaciation.

Moncrief Ridge, which is about 18 miles north of Clear Creek, is similar in composition to Bald and North Ridges. It is also so similar in its topographic relations to the mountain front, to the worn-off mountain top (pl. 18 *B*), and to the bouldery deposits mapped by Blackwelder and Bastin as early glacial drift that the same considerations and tentative conclusions apply to it. The ridge was examined by the present writer in 1923 and again in 1924, but the glacial deposits on North and South Piney Creeks were not visited. The bouldery deposit capping Moncrief Ridge appears to overlie the upturned and beveled strata of the Kingsbury conglomerate member of the Wasatch formation, but the contact is not well exposed. It is not improbable that the base of the ridge is the No. 1 terrace at 5,500 to 6,000 feet above sea level and that there is 500 feet or more of bouldery material overlying that base. (See pl. 19.) The axis of the ridge, which is about 3 miles long, projects obliquely from the adjacent mountain front, and its narrow crest at 6,400 to 6,500 feet is about 300 feet below the upturned and worn-off edges of the Paleozoic limestones and about 300 feet below and 2 to 3 miles distant from the nearest of the early glacial deposits. These deposits lie on a broad high bench between the canyons of North and South Piney Creeks. If the early Pleistocene glacier extended 9 miles farther than that of the Wisconsin stage of glaciation, its terminus lay against the southwest flank of Moncrief Ridge. Evidently here also there is reasonable ground for regarding the ancient bouldery deposit forming the ridge as closely associated with, if not wholly due to, early Pleistocene glaciation, after the development of the No. 1 or Flaxville terraces. The narrow bouldery crest as it now stands resembles a glacial moraine. (See pl. 19 *A*.) Many of the granite boulders range from 5 to 15 feet in diameter. This deposit, together with that of North and Bald Ridges, is therefore tentatively correlated with the early Pleistocene drift of the mountain glaciers on the high benches in front of Glacier National Park. According to Blackwelder,[69] "If the drift here referred to be all early glacial and not partly fluviatile and of uncertain age, South Piney Creek has cut its valley 400 to 600 feet in solid rock since the early glacial epoch." North Piney Creek, after issuing from its mountain gorge, flows eastward at the south side of Moncrief Ridge and 1,000 feet below the level of its crest. Piney and Clear Creeks are tributary to the Powder River. The bouldery deposits comprising Moncrief, Bald, and North Ridges,

[68] In 1924 the writer observed on the north slope of Bald Ridge a little-weathered 5-foot boulder of fine-grained pink granite having a smooth flat face, which showed crescentic markings resembling chatter marks. It is not certain, however, that these marks were really produced by glacial action.

[69] Blackwelder, Eliot, Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 89, 1906.

and the ancient valleys opposite whose mouths they lie, appear to be distinctly younger than the development of the broad subsummit plateau which is overlooked by the high central peaks.

EARLY AND MIDDLE PLEISTOCENE TERRACES

NO. 2 BENCH IN MILK-MISSOURI VALLEY

It appears that No. 1 bench in the Blackfeet Indian Reservation (Glacier National Park region) had not been very deeply dissected before the extension of the first of the mountain glaciers onto it. Farther east, however, the amount of erosion may have gradually increased, so that in the region east of Havre a well-marked valley was being developed below the level of the Flaxville Plain. If the Flaxville Plain is not itself of Pleistocene age, it seems probable that Pleistocene time in this region began with the uplift which caused the streams to cut below the Flaxville Plain—that is, the Pleistocene began a long time prior to the completion of the second set of terraces or No. 2 bench by planation and spreading of the gravel thereon. From the evidence now in hand, it seems necessary to regard the second set of terraces as representing the first of the Pleistocene benches.

No. 2 bench is represented north of Harlem in the Cherry Ridge quadrangle by a broad dissected terrace or bench, 10 to 12 miles in width. Before the erosion of the sharp branching ravines and coulees which now dissect this surface it was a smooth plain sloping gently toward the stream. At the moraine now lying along the edge of the higher plain in the part where Cherrypatch Ridge lowers and flattens out there is an altitude of about 3,000 to 3,200 feet. From this altitude the surface descends about 200 feet in the first mile and flattens thence southward to a slope of 400 or 500 feet in the next 8 to 10 miles, reaching an altitude of 2,500 to 2,600 feet at the crest of the short, abrupt 200-foot slopes and bluffs that now form the sides of the inner valley of the Milk River. The stream flowing in the broad valley represented by this dissected bench must have been at a level now about 2,500 feet above the sea in the region of Harlem—that is, about 600 feet below the Miocene or Pliocene Flaxville Plain to the north.

West of the region of Harlem (west of longitude 109°) a vast area has been eroded below the level of this plain. Only the higher parts, if any, of the area are high enough to reach the level of a plain projected from the No. 2 benches near the mountains to No. 2 bench north of Harlem. The present slope along such a projected plain is about 10 feet to the mile. It may have been about 7 or 8 feet to the mile when graded. No. 2 bench has suffered a good deal of modification, due to several stages of erosion, the last in Recent time, and to mantling by glacial drift. The long, smooth slope of the remnants of this early Pleistocene bench is, however, the principal feature. Though much dissected by erosion, it is fairly well defined on the north side of the Milk River Valley, where seen by the writer, eastward through Phillips County.

About 17 miles north-northeast of Malta the road to Lovejoy climbs to an altitude of 2,570 feet (barometric)—that is, to No. 2 bench 350 to 370 feet above the valley bottom. Overlying the sandstone at the top of the bluff is 10 feet of stratified gravel, and above this is about 30 feet of glacial till. (See pl. 22.) There is in the drift and on its surface an abundance of pebbles and boulders of pre-Cambrian granite from Canada and of limestone, but no granite was seen in the gravel. The pebbles of the gravel are smoothly waterworn and consist principally of brownish quartzite and reddish and greenish siliceous argillite like pebbles of the Flaxville gravel. The material ranges from sand to pebbles 6 inches in diameter, mostly less than 2 inches. Similar gravel-capped remnants of No. 2 bench are preserved above the north bluff of the Milk River Valley in the area between Little Cottonwood and Martin Creeks, in T. 33 N., Rs. 30 and 31 E. Collier and Thom [70] described deposits on one of these tracts as follows:

> The best exposures seen are in sec. 23, T. 33 N., R. 30 E., north of Malta, a few miles from Milk River, where about 25 feet of interstratified gravel and yellowish silt caps the edge of the bench at an altitude of about 2,500 feet above the sea, or 300 feet above Milk River. The gravel is cemented, presumably with calcite, forming a conglomerate that crops out in the form of a small cliff. Fragments of bone and a single tooth were obtained from the face of the cliff. Dr. Gidley identified the tooth as that of a horse resembling the living species and states that it can not be so old as the Flaxville fauna. The formation here rests upon the Judith River formation, but about 5 miles east of this locality it rests upon the Claggett shale and consists of about 25 feet of yellowish silt containing two beds of gravel, one at its base and another 15 feet higher. The gravel is comparatively fine, the pebbles being less than an inch in diameter.

The long slope of the early Pleistocene No. 2 bench is one of the notable features on most of the roads north of the river leading from the undulating higher areas down to the crest of the river bluffs. It is only here and there that the gravel is exposed below the drift in the eroded edge of the bench. The bench has been so much dissected by southward-flowing streams that there are few roads traversing it from east to west. From the longitude of Glasgow eastward in Valley and Roosevelt Counties the No. 2 bench is well marked between the crest of the river bluffs and the Flaxville upland plain as far east as Poplar, as clearly shown on the topographic maps of the Porcupine Valley, Cuskers, Hay Creek, Nashua, Frazer,

[70] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, p. 182, 1918.

Oswego, Wolf Point, Chelsea, and Poplar quadrangles. Here also it is much dissected by southward-flowing streams. Some of the valleys are 200 to 300 feet in depth. This second set of terraces embraces about all the interstream upland tracts between Porcupine and Big Muddy Creeks north of the Milk and Missouri Valleys and below the edge of the Flaxville Plain. The altitude of the Flaxville Plain is about 2,850 feet on the west side of Porcupine Creek and 2,620 feet at its southeast end, in secs. 6 and 7, T. 31 N., R. 52 E. The lower edge of the gently sloping No. 2 bench has an altitude of about 2,250 feet near Nashua and about 2,200 feet near Poplar.

Until the advance of the first continental ice sheet at the Nebraskan stage of glaciation the upper Missouri River probably continued flowing northeastward to Hudson Bay from the vicinity of Poplar along the old abandoned valley described by Bauer,[71] which is well shown on the Poplar, Brockton, and Homestead topographic maps. There is now a certain amount of glacial drift in the bottom and on the sides of this valley, but the broad sag nearly 10 miles in width is a notable feature as seen from an adjacent ridge. Where it is cut across by the present inner valley of the Missouri River the old valley floor "hangs" nearly 250 feet above the present flood plain of the river, or about 2,200 feet above sea level.

While this valley was being eroded the Poplar River, Smoke Creek, Wolf Creek, and Big Muddy Creek and their tributaries were busily engaged in dissecting the Flaxville Plain to the north. The Poplar River joined the Missouri River at a point about 11 miles northeast of the village of Poplar, where the crest of the ridge east of the present lower course of the stream is cut through by a gap about 100 feet in depth. A broad winding channel, not now occupied by a stream, opens eastward to the old valley flat in T. 29 N., R. 52 E. This channel is shown on the Poplar topographic map. Smoke Creek joined the main valley about 13 miles farther northeast, in sec. 1, T. 30 N., R. 53 E., and Wolf Creek and Big Muddy Creek came in near the site of Homestead. In the broad flat east of the latter place is now Medicine Lake (about 1,945 feet above sea level) and a broad belt of sand dunes. South of the old valley is the upland north of Culbertson and Mondak. Quartzite cobblestones are everywhere present on No. 2 bench, mixed with glacial drift, but few exposures of undisturbed gravel have been noted below the drift. Bauer reports the occurrence of 10 feet of quartzite gravel below 42 feet of glacial till at one point in this old valley near Smoke Creek, in T. 30 N., R. 53 E.

The bench east of Havre appears to be an old erosion surface rather than one on which there has been any notable deposition of gravel or sand as on the Flaxville Plain. East of the mouth of the Milk River, on the south side of the Missouri River, the surface is generally much rougher, and No. 2 bench is not known to be preserved. In many places, however, above the more recent slopes and bluffs, there are long, smooth slopes of the early Pleistocene topography.

While No. 2 bench was being developed the Musselshell River probably still flowed northward on the west side of the Larb Hills in what is now the south-north middle course of Beaver Creek and joined the Missouri River near Bowdoin, in eastern Phillips County. The development of No. 2 bench in the Musselshell Valley, as described below (p. 50), was thus in some measure controlled by the level of the stream on No. 2 bench east of Malta.

NO. 2 BENCH AT THE LITTLE ROCKY AND BEARPAW MOUNTAINS

There are notable gravel-covered remnants of No. 2 bench about the Little Rocky Mountains in Blaine and Phillips Counties, and their relations are worthy of some further discussion. (See pl. 35.) Some of the best-preserved remnants are crossed by the Malta road southeast of Zortman. (See pl. 7 *C*.) They are several hundred feet lower than No. 1 bench, about whose eroded north end the road passes in descending to Bear Creek. There are other remnants of this bench near Coburn and Middle Buttes, south of Bear Creek, and also south of Beaver Creek, in sec. 6, T. 25 N., R. 26 E. In 1¼ miles the remnants south of Beaver Creek rise westward from 3,600 feet to 3,950 feet above sea level, where they head at great notches cut in the limestone wall, whence the gravel-depositing streams of this stage issued onto No. 2 bench. (See pl. 23 *A*.) Several such notches "hang" at this altitude 350 to 400 feet above the level at which Beaver Creek now issues from its mountain gorge (pl. 23 *B*) and about 300 feet below the beveled top of the wall where No. 1 bench headed.

No. 2 bench is nearly continuous, though dissected about the northeast flank of the mountains, from Beaver Creek nearly around to Big Warm Springs. This bench also extends eastward in the southern part of T. 26 N., R. 26 E., from secs. 32 to 36 and beyond nearly to the Malta road. In sec. 35 it is cut through by a broad sag, apparently an outlet for glacial waters (p. 99); east of this sag it is partly covered by glacial drift. Like all the others about the Little Rocky Mountains, it is covered with coarse little-worn gravel derived from the local rocks; scattered on top of the local gravel but not intermixed with it on this particular bench, and also on the benches near Coburn Butte, are foreign quartzite pebbles like those of the Flaxville gravel north of Harlem and also glacial boulders of granitic rocks from Canada. The sig-

[71] Bauer, C. M., A sketch of the late Tertiary history of the upper Missouri River: Jour. Geology, vol. 23, pp. 52–58, 1915.

nificance of the presence of these erratics is discussed below (p. 81).

On the east side of Lodgepole Creek and 200 to 250 feet above it is a narrow strip of No. 2 bench in the interval between the main road about the eroded head of No. 1 bench and the great mountain wall of limestone on the south. West of Lodgepole Creek there are several large notches in this wall, and in their bottoms are box canyons from which the present streams issue. Like those near Beaver Creek and similar ones on all sides of the mountains, these notches appear to have been cut while No. 1 bench was being dissected and No. 2 bench was being formed. (See pl. 6 *A*.) There are two remnants of No. 2 bench south of the road from Lodgepole to Hays, in T. 26 N., R. 24 E. One of these remnants in secs. 1, 2, and 11 stands 200 feet above the east bank of Jim Brown Creek. This is dissevered from the mountain wall. The other remnant southeast of Hays is cut by a notable rounded notch through which a road passes. This bench heads at a notch several hundred feet below the beveled top of the upturned limestone where No. 1 bench formerly headed. No. 2 bench is preserved along the west side of the Peoples Creek Valley much of the distance between Hays and the gorge above St. Paul's Mission (pl. 8 *A*), where it is about 100 feet above the valley bottom and 300 to 400 feet below No. 1 bench on the west. In and near the southwestern part of the Fort Belknap Indian Reservation No. 2 bench spreads far out from the west flank of the mountains, and, where not dissected by branching coulees, the flat is almost as smooth as a city pavement. The grade decreases from 200 feet to the mile near the mountains to 25 feet or less to the mile in a distance of 7 or 8 miles. So great has been the erosion south of the mountains that there is little trace of No. 2 bench between Sipary Ann and Saddle Buttes. (See pl. 35.)

Though no fossils have been found in the bench gravel and though there is no drift left by mountain glaciers on any of these benches, nor indeed any evidence of local glaciation in the Little Rocky Mountains, yet from the general relations near Glacier National Park and throughout the region, as described above, it appears that the grading of No. 2 bench may be regarded as having taken place in early Pleistocene time. With this is to be correlated a certain part of the dissection of the mountain mass due to deepening of the gorges; the formation of the box canyons came later.

Apparently erosion has destroyed nearly or quite all remnants of No. 2 bench about the north and west flanks of the Bearpaw Mountains which the writer visited. In 1922, however, Reeves mapped several remnants of a second set of benches near the south and southeast flanks of these mountains in adjacent parts of Blaine and Chouteau Counties, and these may probably be correlated with what is regarded as No. 2 bench about the Little Rocky Mountains. Those dissected by branches of Black Coulee and Birch Creek are much lower than the nearest remnants of No. 1 bench and probably originally extended southward nearly to the line of the present Missouri River gorge at altitudes of about 3,000 feet, corresponding with No. 2 bench of the Judith River Basin. The Missouri River was at that time flowing northward past the west side of the Bearpaw Mountains, and the drainage of the southern slopes of these mountains and of the Judith River Basin probably flowed northwestward to the Missouri River in the sag between the smoothly sloping benches on the north and south.

It is probable that most of the extensive high benchlands west and north of the North Moccasin Mountains between Dog Creek and the Judith River may be correlated with No. 2 bench, as also may some of those west and north of the Judith Mountains. These have not been mapped in detail. One of the benches crossed is 200 to 300 feet above Dog Creek and rises southward toward the North Moccasin Mountains from an altitude of about 3,800 feet (barometric) west of Suffolk.

NO. 2 BENCH IN PONDERA, TETON, LEWIS AND CLARK, AND CASCADE COUNTIES

Extensive remnants of a second set of benches were mapped by Stebinger and Goldman between Birch Creek on the north and the Sun River on the south. One of these on the north side of Dupuyer Creek is crossed by the Park to Park Highway. (See map of Heart Butte quadrangle.) This bench emerges from beneath the terminal moraine of the Birch Creek Glacier (of the Wisconsin stage) 6 to 7 miles west of the village of Dupuyer and slopes thence down eastward at a rate decreasing from about 50 feet to the mile to a point about 4 miles southeast of Valier, beyond which it has been cut away. In the opposite direction, about 12 miles southwest of Dupuyer, the grade steepens to 100 feet to the mile and reaches the mountain front at a level about 400 feet above that at which Birch Creek issues from its mountain gorge 7 miles to the northwest. The relations of the bench to the moraine west of Dupuyer show clearly that it is not a glacial outwash terrace but that it is much older and was dissected before the Birch Creek Glacier extended onto it (p. 119). Remnants of this bench border Muddy Creek between 9 and 16 miles west of Bynum, and still larger remnants border Willow and Deep Creeks between 6 and 25 miles above Choteau. After running for 7 or 8 miles on the highest or No. 1 bench southwest of Choteau the Park to Park Highway drops down to two successively lower benches before reaching the lowest terrace on the

Sun River. The Sun River irrigation canal runs along the slope between these two. The lower one of the two, or perhaps both taken together, belong to the second set of benches. Each of them is about 120 feet below the next higher one where the road crosses. The road cuts expose about 10 feet of coarse gravel, largely reddish quartzite, overlying the eroded surface of the shale. Numerous boulders 1 to 2 feet in diameter were seen on these benches; but none are clearly striated. Gravel of No. 2 bench caps the narrow ridge between the river and Gilman.

A terrace remnant which bevels the upturned edge of the shale north of Gardner's ranch at 4,700 to 4,800 feet above sea level on Elk Creek probably is a part of No. 2 bench, and there is also a remnant of what appears to be No. 2 bench about 100 feet lower than No. 1 bench on the south side of the Flat Creek Valley about 12 miles south of Gilman and 2 to 6 miles northeast of Bean Lake in T. 18 N., R. 6 W. This may have been formed by the Dearborn River when it followed the course of Flat Creek, before the mountain glacier diverted it to its present channel.

No. 2 bench is well preserved for part of the distance between Gilman and Great Falls on the north side of the Sun River. North of Gilman it is 200 to 400 feet above the river. North of Fort Shaw it is about 200 feet above the river, or 3,700 to 3,800 feet above sea level, and several hundred feet below No. 1 bench. Here it is crossed by the Chicago, Milwaukee, St. Paul & Pacific Railway, and on it is the village of Ashuelot. An extensive remnant of No. 2 bench is 300 to 400 feet above the Sun River on the south side of the valley between Dry and Simms Creeks. At least the higher part of the "Sun River Bench" on the south side of the stream and east of Fort Shaw Butte appears to belong to this early Pleistocene stage.

As in the vicinity of Glacier National Park, so throughout this region the relations of the glacial moraines to the upper level of the second set of benches show clearly that the latter were developed and in turn eroded before the Wisconsin stage of glaciation. (See p. 118.) In most places the mountain glaciers of the Wisconsin stage were barely able to surmount the steep and high marginal slopes of outlying remnants of the upper No. 2 bench and override their tops. This is particularly well shown west of Augusta, where the terminal moraine marking the southern limit of the Sun River Glacier loops back to the west several miles before it overtops the eroded west end of a high remnant of No. 2 bench at 4,700 feet above sea level, in sec. 17, T. 20 N., R. 7 W. (See pl. 1.)

CARLOW FLAT, GLACIER COUNTY

It was quite inevitable that, as this study of the several cycles of erosion and consequent terraces was extended farther and farther over the plains, it would be necessary to make some changes in the grouping of the dissevered remnants from those presented in the preliminary paper.[72] One of the most important is the interpretation to be placed on the terrace known as Carlow Flat, between Cut Bank and Browning, in the Blackfeet Indian Reservation, Glacier County. This was at first regarded as one of the typical remnants of a third set of benches.

Further studies, however, in the region farther south and especially about the Wind River Mountains, Wyo., make it fairly certain that it is with Carlow Flat that the terrace north of Dupuyer is to be correlated rather than with the higher drift-covered benches of the Blackfeet Reservation. (See pls. 1 and 37.) Carlow Flat is now regarded by the writer as representing the completion of the main early Pleistocene stage of downcutting and planation and as a correlative of the lower level of the second set of terraces on the Yellowstone (described below, pp. 53, 57) and of the Circle terrace of the Wind River Basin in Wyoming. The relations of the terminal moraine of Two Medicine Glacier to Carlow Flat seem clearly to support this belief and will therefore be presented somewhat in detail. Reference to page 119 shows how closely similar are the relations of the terminal moraines to Carlow Flat and to the second bench north of Dupuyer.

For about 8 miles between Opal and Carlow, west of Cut Bank, Carlow Flat is traversed by the Great Northern Railway. From a dissected margin west of the gorge of Cut Bank Creek, at 3,840 to 3,880 feet above sea level, the smooth flat surface rises gradually in a west-southwesterly direction to about 4,130 feet in 13 miles, an average of 22.3 feet to the mile. At 4,130 feet, in T. 33 N., R. 8 W., the flat is crossed by the terminal moraine of the Two Medicine Glacier of the Wisconsin stage. The relations of the moraine to the gently sloping, gravel-covered plain in this place correspond to those of a moraine bordered by an outwash plain. That Carlow Flat is not primarily due to outwash from the Two Medicine Glacier, however, is unmistakably shown by the relations at the north and south. Carlow Flat is 3 to 5 miles in width from north to south and is cut off from other smaller remnants of the same bench on the north and south by two broad channels more than a mile in width and 100 feet or more in depth. The one on the north is traversed by the Great Northern Railway between Carlow and Bombay; the one on the south (known as Flat Coulee) is traversed by the Two Medicine Canal, and in part of its bottom Spring Creek has cut a channel. The significant fact is that the terminal moraine of the Two Medicine Glacier extends

[72] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 414–415, 1924.

westward down and along the eroded side of the coulee north of Carlow Flat, near Bombay, and on the south it extends down the north side of Flat Coulee, across its bottom for 1½ miles and up the 200-foot slope on the south. This shows clearly that not only did Carlow Flat exist before the Wisconsin stage of glaciation but also that the two broad coulees had been cut into it to a depth of 100 or more feet before the Two Medicine Glacier formed its terminal moraine.

Flat Coulee is a curious remnant of a former and higher channel of Two Medicine Creek. The drainage through it was probably changed several times. The highest floor of the coulee is cut off by the present valley between half a mile and 1½ miles east of the Park to Park Highway. It is, indeed, a beheaded hanging valley whose bottom is the broad sag about 200 feet above Two Medicine Creek, or 4,180 feet above sea level, at the top of the cliff of Horsethief sandstone. The irrigation canal now runs along the base of this cliff and out onto a similar but narrower and lower floor of Flat Coulee at an altitude of 3,980 feet, 3 miles farther northeast. The canal extends thence northeastward through the moraine and along the lowering side slope of the coulee until it reaches and crosses Carlow Flat. The high sag at the top of the sandstone cliff noted above evidently was the channel of the stream when Carlow Flat was formed. The main floor of Flat Coulee marks a later stage when the stream had cut below the flat. At this later stage Cut Bank Creek was confluent with Two Medicine Creek at a point about 8 or 9 miles above their present junction. Still later, in interglacial time, Two Medicine Creek was diverted to approximately its present course along what before was the lower part of Badger Creek Valley. The bench known as Hagan Flat, north of the mouth of Badger Creek, probably represents an intermediate stage of downcutting by Badger Creek.

It appears, if the present correlation of Carlow Flat is accepted, that between the development of the higher drift-covered terraces near the mountains and that of this flat there occurred a cycle during which valleys were deepened 500 feet or more as the result of a notable regional uplift that followed Pliocene time.

It is probable that Greasewood Flat, the gently sloping gravel plain between Cut Bank and Greasewood Creeks, 4 to 6 miles north of Browning, in T. 33 N., R. 11 W., however, is either part of No. 3 bench (p. 59) or an outwash plain of the Cut Bank Glacier. The terminal moraine of this glacier is traceable continuously in a broad sweeping curve across this flat for more than 4 miles in T. 33 N., R. 12 W., about 4 miles west of the Browning-Babb road. At the moraine border in the Cut Bank Valley this flat is 500 feet or more below the upper No. 2 bench on Milk River Ridge, to the north, and near the Glacier National Park automobile road it must have been nearly as low as the present valley bottom—that is, 800 or 900 feet below No. 1 bench, to the north, on which is the old glacial drift.

Relations along the Milk River seem to indicate that the lower level of the set of terraces that is now sharply trenched by the gorge of the North Fork to depths of 200 to 300 feet in the Blackfeet Indian Reservation headed in the broad sag in which Duck Lake lies, at 5,011 feet above sea level. This sag is 4 to 5 miles in width, and its bottom is 300 feet or more below the top of the Hudson Bay divide, to the north, on which is the old glacial drift on No. 1 bench. This sag is directly opposite the Swiftcurrent and Boulder Creek Valleys, and the probabilities are that before the St. Mary River headed south of the international boundary the waters from Swiftcurrent, Boulder, Red Eagle, and upper St. Mary Valleys, flowing at levels 500 feet or more above their present beds, joined and flowed eastward through the Duck Lake sag to the North Fork of the Milk River. At the same time Kennedy Creek probably flowed eastward through the Spider Lake gap, now traversed by the irrigation canal.

Where crossed by the writer in 1920 in southern Alberta, in T. 1 N., R. 22 W., what appears to be the low level of the second bench is represented by a well-marked terrace about 4,100 feet above sea level, or 100 feet above the North Fork of the Milk River. The terrace is capped with coarse cobblestone gravel, including many quartzite boulders 1 to 2 feet in diameter. In 132 miles of its course north of the international boundary (not including meanders) the present valley bottom has an average grade of about 11 feet to the mile, and the slope of what appears to be this lower branch is about 10 feet to the mile. In the 12 miles between the point where the international boundary was crossed by the writer and the point upstream where the North Fork crosses it the grade of the river is about 15.5 feet to the mile, and that of the terrace is about 17 feet to the mile.

A chain of lakes north of Kremlin and 1 to 3 miles west of the Milk River probably marks the line of a preglacial channel of this stream when it cut below No. 2 bench.

It appears that while flowing on the upper level of the second set of terraces, the Missouri River cut a notch at the north end of the Belt Mountains above Cascade and above the mouth of Little Prickly Pear Creek. The stream is now flowing at a level 300 to 400 feet lower. The flat gravel-capped top of a small triangular butte between the mouth of Little Prickly Pear Creek and the village of Wolf Creek probably represents the second set of benches. This is about 3,900 feet (barometric) above sea level and is 400 feet or more above the Missouri River at the mouth of Little Prickly Pear Creek. It seems probable also that the broad gravelly plains constituting the higher parts of the floors of the adjacent intermontane basins northeast, north, and northwest of Helena at 4,000 to 4,400 feet above sea level represent this same stage of terrace formation. The north end of this plain near Canyon Creek is 400 to 1,100 feet below the high bouldery bench (Gravel Range) in the angle between Little Prickly Pear and Canyon Creeks, which is regarded as a remnant of No. 1 bench (p. 17). With No. 2 bench also are probably to be correlated the higher of the gravelly benches that bevel the faulted and upturned Tertiary lake beds in the Missouri Valley below Toston.[73]

So great has been the amount of erosion subsequent to the deposition of the gravel that there are few gravel-capped remnants of the second set of benches in the region of Great Falls between the Missouri River and the Little Belt and Highwood Mountains on the south and east. One tract that may represent this horizon is the gravel-covered flat on which stands the village of Wayne, in T. 19 N., R. 6 E. This flat is crossed by the Custer Battlefield Highway 15 to 20 miles southeast of Great Falls. It is 3,850 feet above sea level, or 300 to 380 feet (barometric) above Belt Creek on the west. A pit near its western edge from which road gravel was taken in 1921 exposed 8 feet of coarse gravel, partly cemented to conglomerate by calcium carbonate. Most of the pebbles are 6 inches or less in diameter, but many are 1 foot or more. Glacial boulders of granite, brought here from Canada by the great ice sheet, are strewn on the surface, but no foreign material is intermingled with the gravel, which was derived by streams from the Little Belt Mountains, to the south. A narrow strip of this bench extends northward between Belt Creek and Red Coulee into secs. 2 and 11, T. 20 N., R. 6 E., where it is crossed by the main road from Great Falls to the Highwood Mountains. Here there is 20 feet of coarse gravel which is about 400 feet above Belt Creek and nearly that much lower than the remnant of No. 1 bench east of the valley. This No. 2 bench is probably, in part at least, the product of Belt Creek at a time before it had even cut its preglacial channel past Waltham (fig. 9) which is now followed by the Chicago, Milwaukee, St. Paul & Pacific Railway for a few miles northward.

The altitude (3,800 feet) of one small gravel-capped butte shown on Fisher's map [74] on the south side of the Missouri River within the bend about 6 miles east of Ulm seems to indicate that it is a remnant of the old valley bottom at this same stage. It is now 400 feet above the river. There may also be some remnants of this terrace farther south on both sides of the Smith River. None were noted, however, by the writer in the course of a trip across this area in 1922.

In the region of Great Falls the lower level of the second set of benches may be represented by the terrace north of the river, at 3,550 feet above sea level, onto which formerly ran the old line of the Montana Central Railway. The plain that is now traversed for some distance northeast of the Boston & Montana smelter by the road to Fort Benton is eroded somewhat below the original flat top. North of this bench is an irregular bluff of dark Colorado shale, which rises abruptly about 200 feet to a higher, gently undulating plain, the Fort Benton Bench.[75] This higher bench, on which is the Benton Lake Reservoir, is either No. 2 bench or an intermediate plain resulting from degradation of No. 1 bench.

East of Black Butte and the Great Northern Railway the terraces are obscured by erosion and by a mantle of glacial drift. To the south and west a gravelly bench extends to the crest of the bluffs bordering the Sun River and Muddy Creek Valleys, except where it is dissected by sharp branching coulees. In 1920 gravel, consisting principally of smoothly rounded quartz, quartzite, and argillite pebbles 2 to 3 inches in diameter, was being taken for road material for the Custer Battlefield Highway from excavations in the lower edge of this bench, at the top of the lower 150 to 200 foot bluff on the north side of the Sun River Valley between Great Falls and Manchester.

This terrace is also represented by the "Ulm Bench"[76] or "Sun River Bench"[77] west of Great Falls, between the converging valleys of the Missouri and Sun Rivers. The soil on this terrace is sandy, but gravel is exposed at some points along the road southwest to Ulm. West of this is a broad sag beyond which the surface rises to the upper No. 2 bench, northeast of Square Butte. When flowing on the lower level of the second terraces the Sun and Missouri Rivers were probably shifting to and fro on a broad plain extending eastward over the present site of the city of Great Falls and to the south and east. The Missouri River had not begun to cut the buried valley south and east of Great Falls, much less its present gorge north of the city.

Doubtless the second set is represented in the benches about the Highwood Mountains, but no careful examination of these benches was made. One No. 2 tract is probably the nearly flat, gently sloping area

[73] Pardee, J. T., Geology and ground-water resources of Townsend Valley, Mont.: U. S. Geol. Survey Water-Supply Paper 539, pp. 6–8, pl. 1, *A*, 1925.

[74] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, pl. 1, 1909.

[75] Fisher, C. A., Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, pl. I, 1909.

[76] Fisher, C. A., Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, pl. 1, 1909.

[77] U. S. Bur. Reclamation map of Sun River project, No. 16306.

southeast of the village of Highwood, between the crest of the south bluff of the Shonkin Sag and the mountains to the south.

There are narrow remnants of two terraces in the valley of Highwood Creek down to a point a few miles above the Chicago, Milwaukee, St. Paul & Pacific Railway crossing. Below this point the gorge is narrow, and the relations are somewhat obscured by glacial drift.

NO. 2 BENCH IN THE JUDITH RIVER BASIN

In the Judith River Basin remnants of No. 2 bench covering many square miles are preserved. Two of the largest and least dissected of these areas lie on both sides of Cottonwood Creek between Lewistown and the Judith River. (See pl. 11 *B*.) So flat and smooth are the surfaces of these great alluvial fans that one riding across them from north to south, toward the Big Snowy Mountains, where they head, scarcely realizes that he is going uphill. As shown by Calvert's contour map,[78] the grade increases gradually from 50 feet to the mile west of the South Moccasin Mountains to about 130 feet to the mile where the present streams emerge from the gorges cut in the upturned edges of the rock in the foothills bordering the mountain slope. At 6 or 7 miles southeast of Moore the bench reaches an altitude of 4,700 feet. The slope down to the north from this altitude is 1,000 feet in 19 miles. On these benches, which are mostly under cultivation, are scattered cobblestones and a few boulders, 1 to 3 feet in diameter, which have been gathered from the fields and laid along the fence lines. The thin loamy clay soil is everywhere underlain by a deposit of coarse gravel. This is not generally reached by plowing in the field but is exposed beneath the top soil in shallow road cuts and gullies, and in some places excavations show as much as 30 feet of the gravel.

Calvert [79] describes this terrace gravel as follows:

> The material is gravel, sometimes rather loosely consolidated, with sand filling the interstitial spaces, but more often it is united firmly by calcareous cement. The lithology of the pebbles indicates their source. In the western area they are composed almost entirely of limestones and occasionally quartzites, which have no doubt been derived from the Madison and underlying formations, for many of the calcareous pebbles contain Mississippian fossils. Near the Snowy Mountains the gravel is likewise composed chiefly of limestone pebbles, but sandstone pebbles are also present. Farther out on the plains the percentage of sandstone decreases, probably because it is less resistant than limestone. The size of the pebbles also varies inversely with the distance from their source. Near the mountains many of the pebbles are of cobblestone dimensions, but they gradually decrease in size as the distance from the mountains increases. The gravel adjacent to the Judith and Moccasin Mountains is composed largely of crystalline pebbles which have been derived from the rocks composing the mountain groups.

The altitude in sec. 1, T. 16 N., R. 16 E., in the northern part of the area mapped by Calvert, is 3,700 feet. An average slope of 17.5 feet to the mile through the intervening 40 miles northward to the Missouri River would reach the upland along the gorge at 3,000 feet.

GRADIENTS ON BRANCHES OF THE UPPER MISSOURI RIVER

On the basis of the present altitudes, with no allowance for any subsequent differential movement, an average fall of about 12 feet to the mile on a projection of No. 2 bench for about 76 miles along the line of the preglacial course of the Judith River would join the Missouri River at 2,775 feet near the big bend east of Virgelle (pl. 1), and an average fall of 12⅛ feet to the mile along the Missouri River for 75 miles northeastward from No. 2 bench at about 3,700 feet, near Great Falls, would connect with the Judith River at the same point. From this point an average fall of 5.5 feet to the mile for 34 miles along the present course of Sandy Creek would reach 2,590 feet south of Havre. Thence eastward 225 miles to the vicinity of Poplar the fall on No. 2 bench is about 1.75 feet. An average grade of about 14 feet to the mile from No. 2 bench west of Dupuyer, in sec. 1, T. 28 N., R. 8 W., projected to and along the course of Marias River to the southward bend 24 miles southeast of Chester, at the east line of T. 29 N., R. 8 E., and thence somewhat north of east across the Lonesome and Boxelder quadrangles (between 2,800 and 3,000 feet above sea level) would join the preglacial Missouri River in the Sandy Creek Valley near Boxelder at 2,650 feet.

NO. 2 BENCH IN MUSSELSHELL VALLEY

Calvert [80] mapped extensive gravel-covered benches sloping eastward toward the lower Musselshell River from the east side of the Judith Mountains.

In 1921 C. E. Dobbin [81] found a gravel terrace bordering the east side of the Musselshell River below Mecaha, in T. 19 N., R. 30 E., at about 2,400 feet above sea level. This is probably the same as the well-marked terrace that borders the west side of this stream from Boxelder Creek northward for some distance to and beyond Mosby. Where examined by the present writer the surface of the latter bench is sprinkled with glacial boulders of red and gray granite. The surface at 2,800 to 2,900 feet above sea level, or 300 to 400 feet above the river at Mosby, is underlain by 5 to 8 feet of gravel with some sand, partly cemented to conglomerate. The smoothly

[78] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, pl. 1, 1909.
[79] Idem, p. 41.
[80] Idem, pl. 1.
[81] Personal communication.

rounded pebbles range in size from a fraction of an inch to 4 inches and consist mostly of gray limestone, red and yellow quartzite, porphyry, and fine-grained igneous rocks such as are found in the gravel on the benches west of Roundup, but with no intermingled granite pebbles like those in the glacial drift.

The height of these terraces is such that if projected northward to Bowdoin at a grade of 2¼ feet to the mile it would overtop whatever filling of glacial drift there is between the present mouth of the Musselshell River and Beaver Creek in southeastern Phillips County, and would connect with the supposed remnant of No. 2 bench north of the Larb Hills at about 2,250 feet above sea level. Mosby is about as far as Havre from the supposed junction of the preglacial Musselshell and preglacial Missouri near Bowdoin—that is, about 100 miles—and the bench in question has about the same altitude at these two places. There seems, therefore, nothing to conflict with the idea that the Musselshell River continued flowing to the Missouri River, which was occupying its preglacial channel in the Milk River Valley, north of the Larb Hills, until after No. 2 bench had been formed. If there is now any considerable depth of glacial drift along this course northward between the present mouth of the Musselshell River and the Beaver Creek Valley, it would seem that the river continued to follow this course also while cutting below No. 2 bench.

Most of the smooth flat gravelly benches described above (p. 23) as mapped by Bowen and by Reeves in the Musselshell Basin north and west of Roundup appear to belong to the second set. The distribution of relatively small remnants of No. 1 bench well out from the mountain fronts and in places nearly to the borders of the inner valley of the Musselshell River shows that No. 1 bench was developed over most, if not all, of that part of the basin west of Roundup. Between these higher remnants and bordering the tops of the side slopes of the inner valleys are the No. 2 benches, in places several miles in width. They bevel the rocks at levels 100 to 200 feet or more lower than No. 1 bench and are themselves covered with coarse gravel beneath a thin loamy soil. The relations show clearly that the Musselshell River and each of its tributaries deepened its valley as the result of some definite change, such as a regional elevation or a lowering of the channel of its master stream, the Missouri River, and either contemporaneously or immediately thereafter the process of planation developed smooth flat valley plains miles in width. No. 2 bench near the Harlowton Cemetery has an altitude of about 4,300 feet (barometric). The grade from this locality to the bench west of Mosby at 2,800 feet (barometric) is thus about 1,500 feet in 140 miles, or at an average rate of nearly 11 feet to the mile. In the same distance the present valley drops about 1,660 feet, or nearly 12 feet to the mile. From the vicinity of the river west of Roundup the grade of the bench increases northwestward from 30 to 100 feet or more to the mile toward the mountains.

Extensive tracts of No. 2 bench occur south of the Musselshell. Those bordering Lebo Creek and American Fork were crossed by the writer on the main road south from Harlowton to Melville. The erosional surface beneath the gravel bevels the formations upturned in the Shawmut anticline.

NO. 2 BENCH ON THE YELLOWSTONE RIVER AND ITS TRIBUTARIES

Finely preserved remnants of No. 2 bench are found at the east front of the Crazy Mountains, some of them cultivated and under irrigation. These border the middle courses of Otter, Big Timber, Swamp, and Little Timber Creeks. These smooth, flat benches slope southeastward with grades of 100 to 200 feet to the mile, and their loamy soil is underlain by coarse gravel derived from the mountains. The streams have cut flat-bottomed valleys with steep bordering bluffs to depths of 200 to 300 feet below the smooth sloping surfaces of the benches.

There are also numerous gravel-capped remnants of No. 2 bench in the Shields River Valley which head at the west and southwest flanks of the Crazy Mountains. One of the most extensive of these is north of Pine Creek and 200 to 500 feet or more above that stream. This heads at one side of the mouth of the canyon at an altitude of about 6,400 feet, slopes thence southwestward at a rate decreasing from about 200 feet to 100 feet to the mile, and terminates at the top of the eroded bluff north of Clyde Park. North of Wilsall, the terminus of the railway branch in 1922, there are remnants of No. 2 bench above the bluffs both east and west of the bottom lands bordering the river. Most of these bench lands are under cultivation, and some of them are irrigated, as are also the lower lands.

Insufficient study of the Yellowstone Valley between Livingston and Gardiner has yet been made to be certain concerning the development of terraces in this part of the valley. A brief examination northwest of Daileys on Big Creek revealed a broad high-level bench or ancient valley bottom at about 6,300 feet above sea level, into which the stream has later cut its inner gorge to a depth of 400 feet or more. (See pl. 24 *A*.) It seems probable that there must have been a definite terrace or bench in the Yellowstone Valley corresponding with so well-marked a feature on this tributary, and that this represents the second stage of valley development and terrace formation. Although the granitic boulders 1 to 20 feet in diameter which lie on the bench and on the slopes for several hundred feet above the bench were probably brought to their resting places from the other side of the Yellowstone Valley by ice of the Wisconsin glacial stage, yet it is possible, in view of the evidence found in the Glacier National Park region, that they were in reality transported by an earlier glacier before the streams had cut below No. 2 bench. In the lower course of Big Creek, however, some distance below the Gallatin National Forest boundary, a great mass of glacial drift extends down into the inner gorge like a later moraine, so that the road has to climb up over it.

On the northeast side of the valley opposite Gardiner is an extensive bench or terrace at 5,800 to 6,000 feet above sea level. This is about 600 feet above the terrace on which the upper part of Gardiner is built and 700 or 800 feet above the river. It is capped with basalt overlying the upturned and beveled edges of Paleozoic and Cretaceous formations. Overlying the basalt in part is a deposit of travertine. The surface of the bench near the road is hummocky like a moraine and is abundantly sprinkled with granitic boulders 1 to 15 feet in diameter. To the north long, smooth, grassy slopes on the granitic rocks bordering Eagle Creek extend gradually down to this bench as to the bottom of an old valley. Bear Gulch deeply transects the bench. It is probable that the erosional surface beneath the basalt represents the bottom of the valley at the stage of No. 2 bench. On this valley bottom basalt was poured out in early Pleistocene time, and subsequently the valley was glaciated. The lower end of the third canyon of the Yellowstone is cut in granitic rock 800 feet or more deep below the upper end of this bench.

South of Big Timber No. 2 bench is well marked along the Yellowstone and Boulder River Valleys. The smoothly sloping gravel-strewn bench is 250 to 300 feet above the Boulder River and about the same distance below the highest bench to the south. With it is probably to be correlated one of the sets of benches farther upstream above and below Livingston,[82] as are also several tracts bordering Upper Deer and Lower Deer Creeks in Sweet Grass County southeast of Big Timber. Farther east down the Yellowstone the inner valley narrows, and planation at this horizon is not so well marked on the sandstone and shale of the Fort Union formation; at least, no remnants of No. 2 bench have yet been noted here. Between Merrill (Springtime post office) and the mouth of the Stillwater River near Columbus there is a well-marked dissected bench extending back a mile or more from the top of the steep 350 to 400 foot bluff of sandstone and shale of the Lance formation. This corresponds with the flat bench above the bluff at the south end of the bridge at Columbus, at an altitude of 3,950 to 4,000 feet. (See Stillwater topographic map, on which what is now Columbus is shown as "Stillwater.") From this bench long smoothly rounded slopes rise to higher levels south of the river. These represent the worn-down mature topography of the upland that bordered the valley when the stream was flowing on No. 2 bench. These slopes and the bench are now dissected by sharply cut valleys of later stages of erosion. The bench south of the Columbus bridge is 350 to 400 feet above the river and is capped with smoothly rounded coarse gravel, with some cobblestones 1 foot in length. The material is partly reddish quartzite and largely granite, diorite, porphyry, and various other crystalline rocks; no limestone pebbles were seen. Apparently the gravel at this place came very largely from the Beartooth Mountains at the head of the Stillwater River and its tributaries, inasmuch as the constituent material is mostly different from that in the lower terrace on the north side of the Yellowstone west of Columbus.

For 6 to 8 miles west of Absarokee on the south side of the Stillwater Valley there are remnants of No. 2 bench. One of these is nearly 300 feet above the stream. It is covered with coarse waterworn gravel ranging from fine material to stones 1 foot in diameter and consisting mostly of granite and other crystalline rocks.

No careful examination was made of the upland near the Stillwater River farther east. Bordering the tributaries of the stream, however, from Absarokee southwestward to the Beartooth Mountains, is a very fine development of the second set of terraces. These tracts comprise a large part of the "terrace gravel" areas mapped by Calvert.[83] The flat, smooth, gently sloping surfaces extend for miles at the top of the steep sides of the valleys, 200 to 400 feet above the present streams. The bench on the east side of East Rosebud Creek, though very narrow in places, is continuous for nearly 12 miles in Ts. 5 and 6 S., R. 18 E., and in this distance declines northward from an altitude of 6,100 feet near the mountains to 4,800 feet. From a slope of more than 200 feet to the mile near the mountain front the grade decreases in 12 miles to less than 100 feet to the mile. (See pl. 47.)

No. 2 bench is very well developed along the east side of Rock Creek near and north of Red Lodge just outside the area mapped by Calvert. There are some small remnants in the lower part of the canyon, and at the canyon mouth No. 2 bench extends across the beveled edge of the upturned Paleozoic limestone (pl. 13 *B*), about 300 feet above the valley bottom. About a mile farther north a steep slope rises 250 feet

[82] Calvert, W. R., The Livingston and Trail Creek coal fields, Park, Gallatin, and Sweet Grass Counties, Mont.: U. S. Geol. Survey Bull. 471, pl. 29, 1912.

[83] Calvert, W. R., Geology of the Upper Stillwater Basin, Stillwater and Carbon Counties, Mont.: U. S. Geol. Survey Bull. 641, pl. 21, 1917.

from No. 2 bench at an altitude of 5,900 feet to No. 1 bench, which continues north past Red Lodge (pl. 13 *A*), where No. 2 bench again appears. In 14 miles it declines nearly 1,300 feet, from 5,900 to 4,660 feet (barometric) east of Roberts. This bench has a width of less than a mile, and east of it, where not cut by the sharp erosion of later stages, smoothly worn slopes rise to adjacent higher lands. Northeast of Roberts only small remnants of this bench are preserved at intervals. The main bench on the west side of Rock Creek has an initial height south of Red Lodge nearly the same as No. 2 bench on the east side of the valley. It declines northward more rapidly, however, and at Roberts is 50 to 60 feet lower than No. 2 bench on the east side of the valley. This finely developed and irrigated bench, 1 to 2 miles in width, mapped by Calvert on the west side of Rock Creek Valley near and north of Red Lodge, thus appears to represent No. 2 bench as finally left by the stream when it cut down to its present level. This relation has some significance when an attempt is made to correlate the benches along the Yellowstone below the mouth of Clark Fork.

The higher of the small bench remnants on Rock Creek near Boyd and Joliet and the terrace about 100 feet above the railroad at Silesia may represent the upper level of No. 2 bench. It should be noted that there are in many places certain intermediate benches, so that it is not everywhere clear just which ones represent the main stages. This is perhaps not a very serious matter, however, if the fact of such intermediate stages is clearly recognized.

Remnants of No. 2 bench were examined on both sides of the valley of Clark Fork of the Yellowstone River north and east of Fromberg, where they are about 200 feet above the bottom land. The coarse gravel here contains boulders 1 to 1½ feet in diameter and consists mostly of crystalline rock with a few or no limestone or quartzite pebbles. Near the cemetery south of Belfry a remnant of the bench is about 3,850 feet above sea level. Just east of the bridge at J. F. Allen's ranch, which is 2 miles north of the Montana-Wyoming line, a remnant is about 220 feet above the stream, or 3,900 feet (barometric) above sea level—a rise of nearly 300 feet in about 30 miles upstream. At this place there are some stones 1 by 2 by 3 feet in size. The pebbles are mostly 1 to 4 inches in diameter and smoothly rounded; they are chiefly of crystalline rock, with little or no quartzite, agate, or silicified wood. There are considerable amounts of limestone pebbles, and solution and redeposition of calcium carbonate from these has cemented the gravel to a conglomerate, which projects as a ledge 20 feet thick. (See pl. 22 *B*.) Many of the crystalline pebbles are disintegrating. There also appear to be other more extensive remnants of this No. 2 bench between the valley and the mountain front 9 or 10 miles to the west. About 3 miles south of the State line there are three small remnants at about 4,300 feet above sea level. At this place, which is 8 or 10 miles from the nearest point of the mountains to the west and 12 or 13 miles downstream from the mouth of the Clark Fork Canyon, most of the pebbles are 2 to 4 inches in diameter, but there are many boulders 1 to 2 feet in diameter and some 3 to 6 feet. (See pl. 5 *B*.)

The average gradient as projected from these gravel-capped buttes to a similar one at an altitude of about 4,950 feet (barometric) about 6 miles farther west is about 100 feet to the mile. The latter, a remnant of No. 2 bench, forms the flat top of a mesa 300 feet high, about 3 miles north of Clark post office, Wyo. A normal increase in gradient westward to 200 feet to the mile across the intervening 5 miles would clear the tops of most, if not all, of the foothills and would extend this bench to the mountain front at about 6,000 feet. A continuation of the grade of 100 feet to the mile along the river from the three remnants of No. 2 bench up the valley and into the canyon would extend this terrace to the lower part of the broad bench above the walls of the inner box canyon near the trail 6 miles above the canyon mouth (pls. 13 *C* and 25 *A*), at about 6,300 feet. It seems probable, therefore, that by the time No. 2 bench was completed the cutting of the inner box canyon had not progressed to any great depth nor more than 5 miles up the canyon from the mountain front.

The broad lower gravel terrace that spreads out in the angle between the converging Clark Fork and the Yellowstone is below the upper level of No. 2 set and corresponds with the lower terrace as developed on the west side of Rock Creek at and below Red Lodge. At first sight it may seem that this must be a distinctly later terrace, and, indeed, it may be. As indicated below, however (p. 56), there are remnants of two rather closely associated terraces on the Yellowstone east of Billings which are not readily differentiated as marking two distinct stages of regional uplift. There are also indications that for some distance east and west of Billings, where the Yellowstone crosses the Pryor Mountain anticline, the stream has not cut so far below No. 2 bench as farther east and west. With the lower terrace in the angle between Clark Fork and Yellowstone River at 3,350 to 3,380 feet (barometric) is correlated the broad gravel terrace north and east of Laurel. This is continuous northeastward down the north side of the valley nearly to Billings.

Both levels of the second set are crossed in numerous places below Forsyth by the Yellowstone Trail. Possibly a minor uplift interrupted development of No. 2 bench, or it may be that this break marks the time when the Missouri River was diverted from Hudson Bay to the Mississippi Basin and began the cutting of its new gorge through the Dakotas. In relocating across the dissected plain outside the border of the Keewatin ice sheet the stream would first cut through the crests of the divides and perhaps lower its bed rather rapidly. As the transected divides broadened at lower levels the rate of downcutting would become slower, and as the stream approached grade it would tend to broaden the valley bottom and develop a new flood plain.

This part of the bench is irrigated and mostly under intensive cultivation. At Billings the terrace has been cut away. Passing the east end of the great sandstone bluff, the Yellowstone Trail runs up onto this bench north of the Fair Grounds at 3,200 feet (barometric) and continues thereon 100 feet or more above the river to the bridge north of Huntley. The terrace extends north to Shepherd and thence northeastward 6 or 8 miles or more before it is cut away by the river's swinging to the north side of the valley. Much of this part of the terrace also is irrigated, and near Billings there are many truck farms upon it. Gravel, which underlies the loamy soil, is excavated in several pits near the Fair Grounds and is exposed along the eroded margin and in the sides of coulees. There are traces of this terrace along the south side of the valley from Huntley eastward.[84] East of Ballantine the terrace broadens below the High Line Canal, from which it is irrigated, and for 3 or 4 miles it is traversed by the Chicago, Burlington & Quincy Railroad. From the foot of the bluff below this terrace the lower irrigated valley flat slopes gently northward 2 to 4 miles to the river. Pompeys Pillar (pl. 26 *A*) is a bit of the sandstone ledge underlying No. 2 bench which was left when the river cut down to its present bed. North of Anita station the terrace is nearly 2 miles wide. Corresponding narrow benches border the Fly Creek Valley for several miles southward. This stream has cut 100 to 150 feet below the terrace. From the village of Pompeys Pillar eastward to Custer No. 2 bench is narrow on the south side of the valley and much dissected by streams from the south. It appears to be better preserved on the north side of the valley, but the writer has seen that part only from a distance. East of Custer the Yellowstone Valley is abruptly constricted by a ledge of Lance sandstone, and upon this No. 2 bench extends nearly 2 miles northward directly across the valley to the river bank, at an altitude of 2,850 feet (barometric), 150 feet or more above the water. This terrace was mapped by Rogers.[85] The Yellowstone Trail crosses the river northeast of Custer and runs eastward a short distance below the picturesque sandstone bluff shown in Plate 26 *B*, thence up onto No. 2 bench, 125 feet above the river. Here and also south of the stream above the railway tunnel there are two different levels to the bench. From 10 to 15 feet of coarse gravel is exposed in cuts near the top of the bluff. The pebbles are smoothly waterworn and range from a fraction of an inch to 8 inches in diameter. Besides plentiful red and yellow quartzite pebbles there is a great variety of granitic, porphyritic, and other crystalline rocks derived from the mountains to the south and west. Few, if any, pebbles of limestone are present.

East of Custer the Yellowstone River is joined by the Big Horn River, and at Hardin, about 30 miles to the south, the Big Horn is joined by the Little Horn, which heads in the Big Horn Mountains near the Wyoming-Montana State line. The Big Horn River cuts through the north end of the Big Horn Mountains in a deep, narrow canyon. It emerges from between the walls of upturned Pennsylvania limestone at the mountain front, about 35 miles southwest of Hardin, onto a broad alluvial flat which ranges from 2 to 4 miles in width and which is mostly irrigated and under cultivation. Northward to a point about 7 miles above Hardin the river flows mostly at the west side of this flat at the foot of an abrupt line of bluffs, 100 feet or more in height. From the crest of these bluffs a broad flat terrace, No. 2 bench, extends westward to the eroded slopes of the bordering uplands. (See Thom's description, pp. 27–28.) The main terrace is considerably eroded for about 6 miles below the canyon. From this point, where it has an altitude of 3,250 feet, northward to Hardin, it is well preserved, except for transecting coulees. It is 500 feet or more below the remnants of No. 1 bench to the west. Gravel underlying the soil on No. 2 bench was examined by the writer near the bridge and irrigation dam south of Two Leggin Creek. The well-rounded pebbles are largely dense crystalline rocks, with some limestone, pink, yellow, and red quartzites, like those of the Belt series, and yellow chert. There is not the great variety of porphyritic rocks such as are found in bench gravel along the Yellowstone. A lower gravel terrace (No. 3) is present below the mouth of the canyon, and here there is an abundance of limestone pebbles and boulders. West of Hardin, No. 2 bench where crossed by the Custer Battlefield Highway is more than 3 miles wide and carries fine farms. About 7 miles above Hardin the river swings across to the east side of the flat and leaves the broad lower plain on the west side of the river. In this part the surface drops 50 to 100 feet from No. 2 bench to the lower plain by an abrupt marginal slope.

East of Hardin the site of old Fort Custer is on a remnant of No. 2 bench which occupies the angle between the converging Big Horn and Little Horn Rivers. The bench here is 200 feet above the level of

[84] Hancock, E. T., Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pl. 14, 1920.

[85] Rogers, G. S., Geology and coal resources of the area southwest of Custer, Yellowstone and Big Horn Counties, Mont.: U. S. Geol. Survey Bull. 541, pl. 28, 1912.

their confluence at the top of nearly vertical bluffs. Southward from this locality to and beyond the vicinity of Custer Battlefield the Little Horn is bordered on the west by a narrow strip of the same terrace. Where examined by the writer the gravel on this terrace is mostly limestone, with fewer pebbles of granite and porphyry than on the terrace along the Big Horn and so far as noted none of Belt (?) quartzite.

Remnants of two levels of No. 2 bench, capped with limestone gravel, were noted nearly as far south as Wyola, 250 to 450 feet above the stream. (See also pp. 27–28.) North of the vicinity of Hardin there appear to be remnants of No. 2 bench on both sides of the river, but these are narrow and much dissected. North of the sharp bend 16 miles below Hardin the road to Custer in places runs up onto No. 2 bench, and east of this place the Big Horn terrace merges with that on the Yellowstone. In 56 miles below the canyon this No. 2 bench in the Big Horn Valley descends 400 feet, from 3,250 to 2,850 feet above sea level, or at an average rate of about 7 feet to the mile.

The quartzite pebbles and a large part, at least, of those of crystalline rocks were brought through the Big Horn Canyon at either this or an earlier stage from formations in or west of the Big Horn Basin and did not come from the Pryor or Big Horn Mountains.

TERRACES EAST OF THE BIG HORN MOUNTAINS

Darton and Fisher [86] mapped and described extensive gravel-covered terraces bordering the east side of the Big Horn Mountains, Wyo., and on a later map Taff [87] showed these terraces as extending eastward to Goose and Little Goose Creeks north and south of Sheridan. Some of these were also examined in a brief reconnaissance by the present writer in 1923. In character and topographic relations they are so similar to terraces of the Big Horn Basin and the Yellowstone and its tributaries in Montana that there can be no doubt that they have a corresponding history. The terraces west of Parkman are on tributaries of the Little Horn River. Those farther south in Sheridan County border the Tongue River and its tributaries. But little of the valley of the Tongue River in Montana has been examined by the writer. The best preserved of these terraces between the mountains and Sheridan comprise extensive smooth, flat benches 50 to 100 feet above the rather broad, flat bottom lands along the several streams. These terraces appear to correspond to the lower level of the second set of terraces of the region. On this set of terraces are Fort Mackenzie, the fair grounds west of Sheridan, and the cemetery southwest of Sheridan. From these localities the terrace is preserved almost continuously up the streams to the foot slopes of the mountains, 4,500 feet or more above sea level. Near the mountains the terraces of this set rise to or merge with the head of a higher but less extensively preserved set of benches or mesas, which appear to represent the upper level of the No. 2 terraces as elsewhere found. This relation is illustrated between Wolf and Goose Creeks west of Beckton, where the narrow upper flat overlooks the more extensive lower one on the north from heights of 100 to several hundred feet. These benches appear to be remnants of what must originally have been continuous or nearly coalescent alluvial fans forming a smooth sloping piedmont plain. The remnants are now 400 to 500 feet above the present streams and they appear to be preserved only within 4 or 5 miles of the mountain front. They truncate the upturned edges of the red beds and head at or near the foot of the great sloping limestone wall at altitudes ranging from 5,000 to 5,500 feet.

Taff's map does not show any remnants of these No. 2 terraces east of Sheridan. From Moncrief Ridge northward, probably none of the drainage from the mountains at these stages went farther east than Prairiedog, McCormick, or Goose Creeks before being diverted to the Tongue River. A large part of the lower No. 2 benches, some of the upper level, part of the gentler slopes below, and the bottom lands are under irrigation and carry fine farms.

None of the mountain glaciers approached within 5 or 6 miles of the canyon mouths at the Wisconsin stage, so that the relation of the glacial waters to the lower of these terraces is not clearly indicated. It is probable, however, that the streams had already cut below the lower No. 2 terraces and were flowing on the bottom lands when the Wisconsin stage began.

A few remnants such as the gravel-capped top of the Beaver Creek Hills, 7 or 8 miles southwest of Sheridan, and the narrow spur extending north from the foot of Moncrief Ridge may represent a still higher plain intermediate between the No. 2 set and the plain of the top of the latter ridge.

From Piney Creek, near the Sheridan-Johnson County line, in T. 53 N., southward, the drainage from the mountains flows in a general northeasterly direction to the Powder River, and numerous remnants of the gravel-covered terraces and benches are preserved between them, as shown on Darton and Fisher's map of the Fort McKinney quadrangle. Most of these appear to belong to either the upper or the lower level of the No. 2 set. Their character and relations are much the same as in the Sheridan and Dayton quadrangles to the north.

[86] Darton, N. H., and Salisbury, R. D., U. S. Geol. Survey Geol. Atlas, Bald Mountain-Dayton folio (No. 141), 1906; Cloud Peak-Fort McKinney folio (No. 142), 1906.

[87] Taff, J. A., The Sheridan coal field, Wyoming: U. S. Geol. Survey Bull. 341, pl. 8, 1909.

The following description is given by Gale and Wegemann:[88]

Skirting the foothills of the Big Horn Mountains and extending down the valleys of the principal streams that head within the mountains is a series of remarkably well-developed gravel-covered terraces. Some of them form broad alluvial plains for a distance of 5 to 10 miles from the mountains, but beyond these plains they are confined to the larger stream valleys, which they follow for great distances. In some places four or five of these gravel-covered terraces may be observed from one point, rising one above another. The slope of their surfaces away from the mountains is usually pronounced. The gravel cap is composed of rounded stream material which varies in size from small pebbles to fair-sized boulders and whose constituents represent most of the igneous and sedimentary rocks exposed in the mountains near by, from which they were probably derived.

The mantle of sand and gravel on these surfaces is not heavy, a fair estimate being perhaps 5 to 10 feet on the stream terraces. Nearer the mountains the gravel is thicker, but probably its thickness does not exceed 40 or 50 feet in most places. On the surface the gravel has been concentrated by subaerial erosion into a layer 6 to 10 inches thick, forming a protecting cap to the terrace which tends to check its further degradation. This feature is well represented along Crazy Woman Creek near Trabing, where the gravel terraces form a line of low hills along the stream valley, the country back of them, which is covered by a thinner mantle of gravel, having been reduced to a somewhat lower level. Unmistakable glacial polishing was observed on boulders included in some of these deposits. One locality in which the glacial pebbles were found is on a broad terrace 1 mile north of Buffalo, in the SW. ¼ sec. 23, T. 51 N., R. 82 W.

The higher gravel-capped mesas southeast of the Cross H ranch, which is 6 miles south of Buffalo, appear to be remnants of a terrace higher than the upper No. 2 level. The terraces along the Powder River between those of the Fort McKinney quadrangle and the great terrace on the lower course of the stream south of Terry, Mont., have not yet been mapped.

NO. 2 TERRACE ON THE LOWER YELLOWSTONE

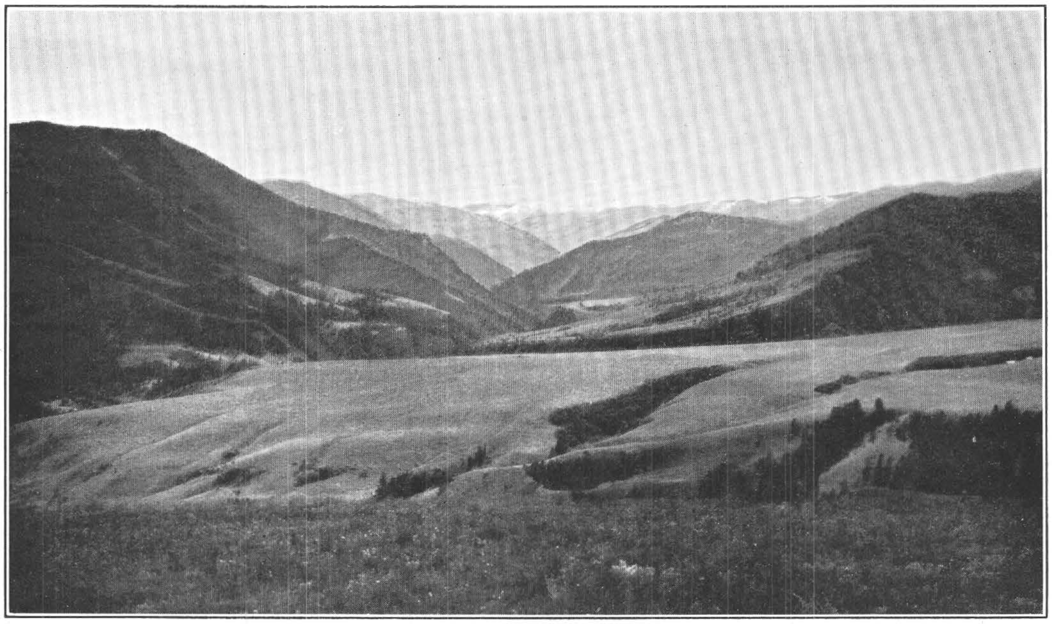
There is some uncertainty about the correlation of the remnants of No. 1 and No. 2 benches between the mouth of the Big Horn River and Miles City. The relatively low height of the representatives of No. 2 bench above the Big Horn River and the Yellowstone west of Custer introduces some confusion, but they seem to have been continuous with the prominent bench near the Powder River south of Terry, which, in turn, appears to be correlative with No. 2 bench in the region of Glendive. Without attempting to clear up the matter finally with the data now in hand, the description may proceed with what seem to be remnants of two levels of the second set of terraces.

Bench No. 2 appears to be nearly continuous east of Custer at the top of the bluff north of the river most of the distance from the point where the Yellowstone Trail runs down off the bluff eastward to the Chicago, Milwaukee, St. Paul & Pacific Railway in Rosebud County, but it has been examined by the writer at only one or two places. South of the river it is represented in places by two distinct levels. Near Myers the bluff capped with Lance sandstone rises to a still higher bench (No. 1 (?)). About 6 miles west of Forsyth the sandstone of the Lance formation comes down lower into the bluffs, and, owing to its somewhat more resistant character than that of the underlying shale, the inner valley gradually narrows again to a width of about a mile at Forsyth.

From the mouth of the Big Horn River eastward for some distance the river has cut to increasingly greater depths below No. 2 bench. South of Forsyth the gravel caps the sandstone bluff at an altitude of 2,775 feet (barometric), 250 feet above the Northern Pacific Railway (pl. 27 *A*) or nearly 300 feet above the river, and on the north side of the valley it occurs on two somewhat lower levels, 2,730 and 2,660 feet (barometric) at the top of the bluff near the Chicago, Milwaukee, St. Paul & Pacific Railway station. Many of the pebbles here are 8 to 10 inches in maximum diameter, and there are some stones 1 to 2 feet long. About 3 miles east of Forsyth the Yellowstone Trail on the south side of the valley runs up the bluff to a very extensive flat bench (pl. 27 *B*) on which are many farms. This is continuous eastward to Rosebud Creek at 2,600 to 2,700 feet above sea level, or 200 feet above the river. The Yellowstone Trail descends to cross Rosebud Creek but climbs again to the bench east of the village of Rosebud. All along here the two levels of No. 2 bench are well developed. From the bench east of Sweeney Creek the Yellowstone Trail runs down to the railway and follows this to Clermont siding. From this point eastward the road runs up onto and down off the bench repeatedly. Here and there are lower remnants, probably of No. 3 bench.

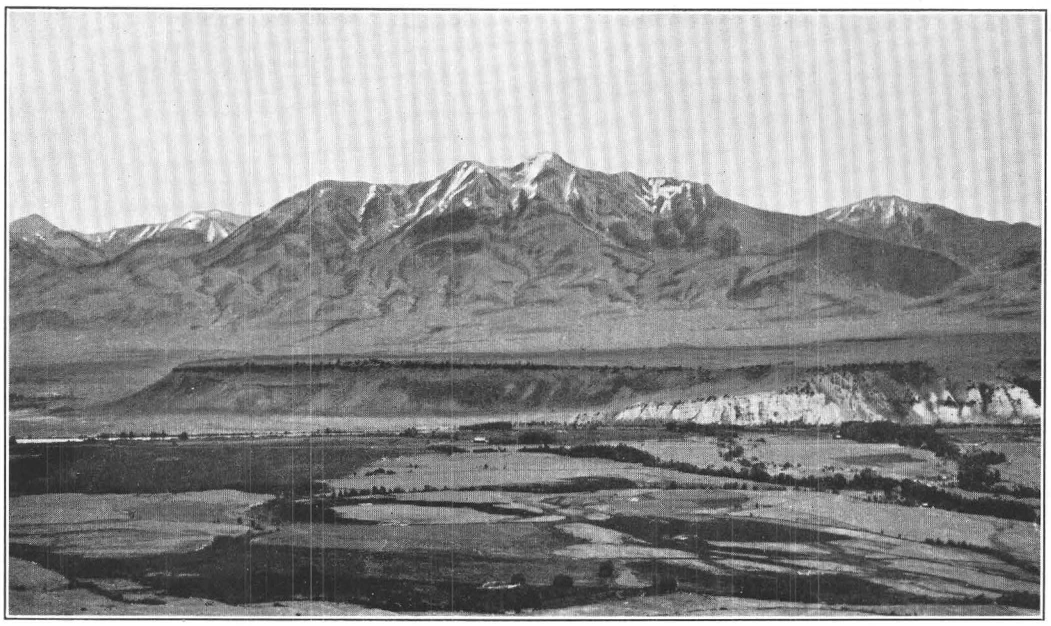
The gravel is well exposed in the Northern Pacific Railway gravel pit on this bench south of Horton, at 2,650 feet (barometric) above sea level. The sides of the pit show at the top 1 to 3 feet of clay soil, dark above and whitish gray below, owing to caliche concentration of calcium carbonate. Below the clay is about 30 feet of interbedded gravel and sand. The pebbles are smoothly rounded and mostly less than 1 inch in diameter, but a considerable percentage range from 1 to 3 inches, and some are 6 to 8 inches. They consist of vein quartz, brownish quartzite, reddish siliceous argillite (like the Belt rocks), jasper, chalcedony, pink and gray granite, and various porphyritic igneous rocks. Occasionally pebbles of chalcedonized wood are found, and one pebble contained a silicified cup coral. The distribution of the Pleisto-

[88] Gale, H. S., and Wegemann, C. H., The Buffalo coal field, Wyoming: U. S. Geol. Survey Bull. 381, p. 138, 1910.



A. VIEW UP BIG CREEK 8 MILES WEST OF EMIGRANT PEAK

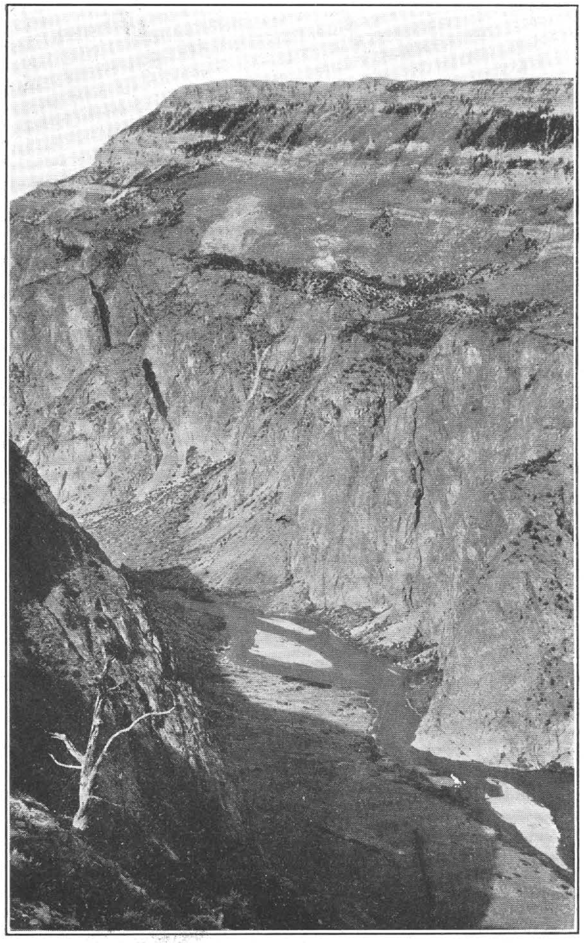
Showing the broad upper valley, probably equivalent to the No. 2 bench (early Pleistocene), in the bottom of which is cut a gorge several hundred feet deep.



B. VIEW SOUTHEAST ACROSS YELLOWSTONE VALLEY TO EMIGRANT PEAK

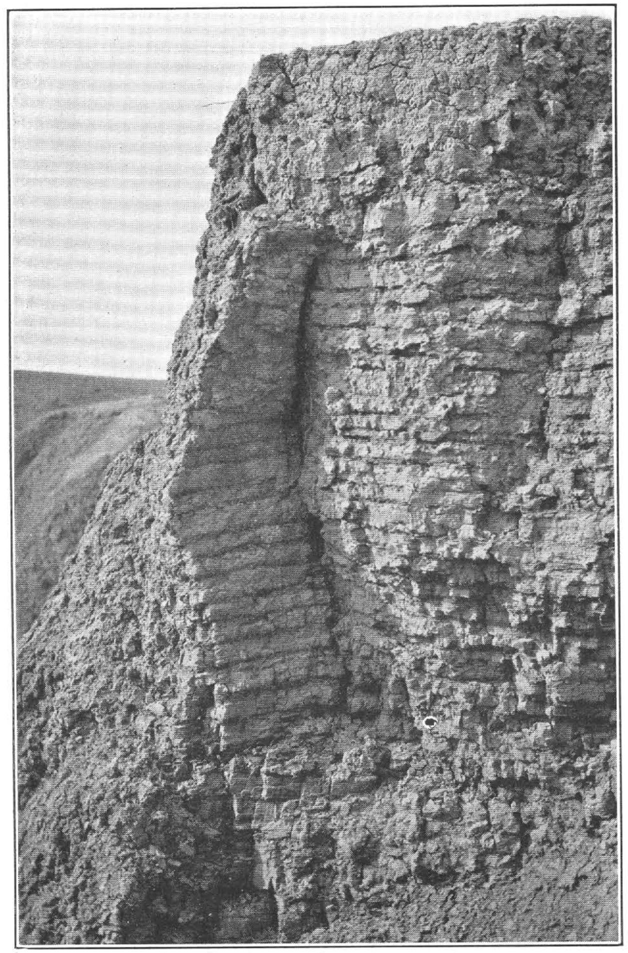
Showing the broad basalt-capped bench. This is thinly covered with glacial drift, and below, at White Cliffs, is exposed 80 feet of gravel unconformably overlying tilted and eroded cream-colored Tertiary clay (Bozeman "lake beds").

YELLOWSTONE RIVER ABOVE LIVINGSTON, MONT.



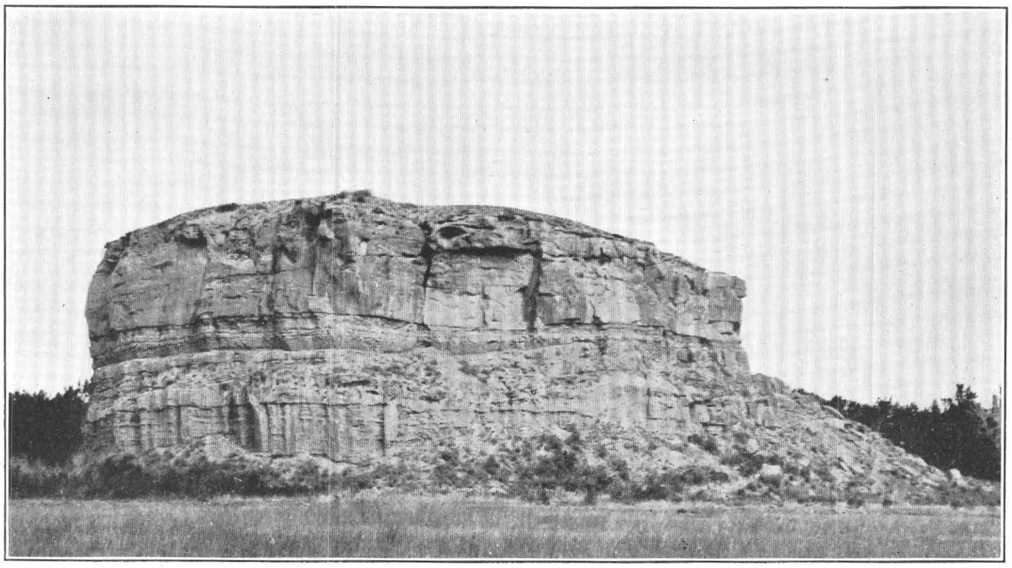
A. INNER BOX CANYON OF CLARK FORK OF THE YELLOWSTONE RIVER, WYO.

Cut in Pleistocene time about 1,300 feet into granite and gneiss below the upper wall of Paleozoic rocks.



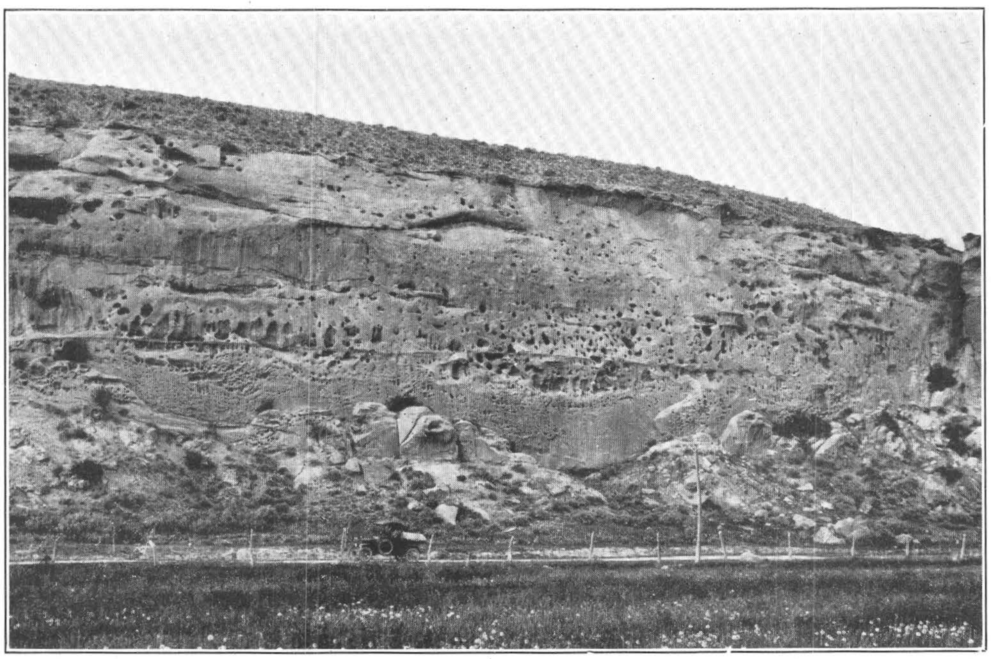
B. LAMINATED CLAYS OF GLACIAL LAKE CUT BANK, GLACIER COUNTY, MONT.

Photograph by Eugene Stebinger.



A. POMPEYS PILLAR, 30 MILES NORTHEAST OF BILLINGS

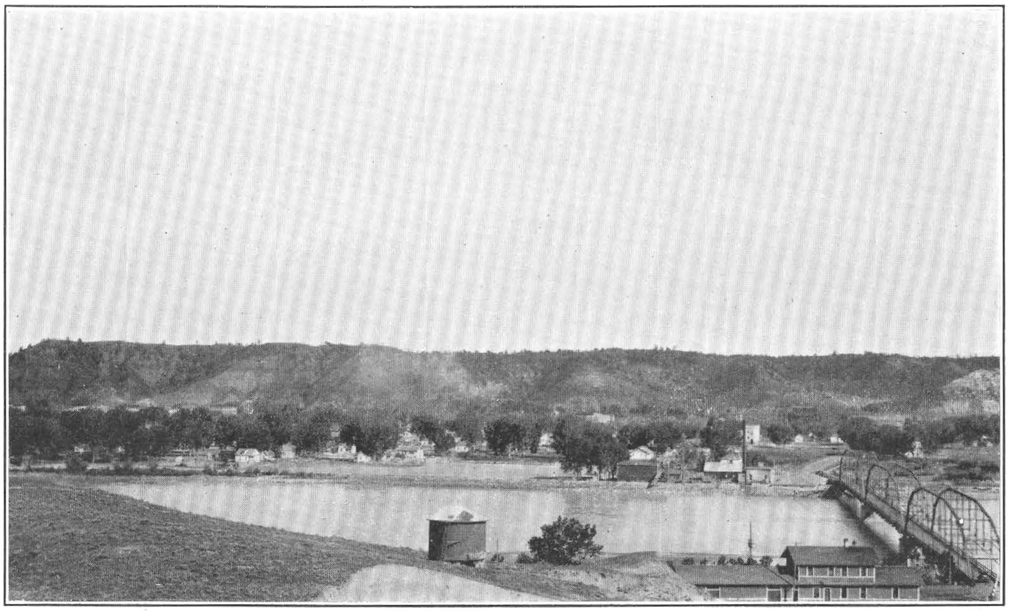
An erosion remnant of Lance sandstone in the valley. On the opposite side toward the river, Capt. William Clark, of the Lewis and Clark expedition, cut his name and the date, July 25, 1806.



B. BLUFF OF LANCE SANDSTONE EAST OF CUSTER

Capped with quartzite stream gravel of the second terrace (No. 2 bench). The face of the cliff shows the effects of differential weathering of the friable sandstone.

YELLOWSTONE RIVER, MONT.



A. BLUFF SOUTH OF FORSYTH

This bluff of Lance sandstone and shale is capped with quartzite river gravel of the second terrace (No. 2 bench), 250 to 300 feet above the river.

B. SMOOTH, FLAT SURFACE OF THE GRAVELLY SECOND TERRACE (No. 2 BENCH) 3 TO 10 MILES EAST OF FORSYTH

Traversed by the Yellowstone Trail; 200 feet or more above the river.

YELLOWSTONE RIVER, MONT.

cene terraces across Rosebud County, as shown on Plate 1, is taken in part from Renick.[39]

At Miles City the terrace on the northwest side of the river is about 250 feet above the stream, or 2,600 feet (barometric) above sea level. The gravel here is generally covered by clay soil so that it does not usually show in the plowed fields, but it is exposed at the top of the bluff near the bridge. Near and east of Miles City the Yellowstone Trail closely follows the Northern Pacific Railway on the valley bottom. East of Tusler it climbs 275 feet to a gravel bench at 2,620 feet, which must belong to the second set, and then drops to a broad, somewhat lower terrace at 2,570 feet. The road leaves this terrace near Shirley and continues thence northeastward beyond Blatchford on the broad valley flat. At 300 feet above this flat on the southeast is a broad gravel-covered bench (No. 2), which extends northeastward nearly or quite to the Powder River. So far as could be seen from a distance there are no remnants of this bench on the opposite side of the valley between Sunday Creek near Miles City and Terry.

The Powder River, which joins the Yellowstone from the south at a point 8 miles above Terry, is bordered by a finely preserved terrace several miles in width. The inner bluff of the Yellowstone Valley cuts directly across this terrace south of Terry. Taking the main road south from Terry, which is 2,264 feet above sea level, the writer crossed the broad lower terrace on which the village stands and ascended the 300-foot bluff. (See pl. 1.) From its crest the flat terrace or bench, several miles in width, rises gently southward between higher land on the east and west. At a distance of 15 miles south of Terry the barometer registered 2,600 feet. This flat is underlain by stratified sand and fine gravel, apparently not more than 20 or 30 feet deep, overlying shale of the Fort Union formation. When the Powder River was flowing on this broad valley plain, which appears to correspond to the final stage of the second set of terraces, it evidently went directly north and joined the Yellowstone near or below Terry. It is now intrenched in a much narrower inner gorge cut nearly 300 feet along the west side of the older valley and joins the Yellowstone 8 or 10 miles farther upstream than before. The pebbles on this No. 2 bench are mostly yellow chert, quartzite, agate, some few of granite, dense dark and greenish crystalline rocks, and some etched limestone and silicified wood.

About 4 miles east of Terry the bluff swings north nearly to the river, and above it is a remnant of No. 2 bench 3 miles in width and 2,590 feet (barometric) above sea level. There are some fine farms on this part of No. 2 bench, which is more than 350 feet above the river. The soil is rather sandy and appears to be underlain by coarse gravel, as such gravel is exposed in road cuts at the margins. The Chicago, Milwaukee, St. Paul & Pacific Railway runs about the point of the bluff on the lower (No. 3) bench to enter the O'Fallon Creek Valley on the east. There is also a very broad gravelly bench at a corresponding level northeast of O'Fallon Creek. This bench extends northward to the top of the bluff on the southeast side of the Yellowstone to the vicinity of Marsh, and it is crossed by the Yellowstone Trail on the route to Baker. Long, low slopes rise back of the terrace where they are not sharply dissected by more recent erosion. Evidently when the streams were on No. 2 bench they were bordered in large part by smooth, rolling, little-dissected uplands of moderate slope.

As nearly as can be determined, the average grade of No. 2 bench between Billings and Terry is between 3 and 4 feet to the mile. Crossing the Yellowstone near Fallon on the Red Trail to Glendive or traveling on the Northern Pacific Railway, the observer may see the abrupt slopes or bluffs below the flat benches off to the west. There are numerous dissevered remnants of No. 2 bench west of Marsh, and several of these in the Glendive quadrangle were traversed by the writer.

The gravel is similar to that on No. 1 bench, the pebbles being mostly rounded and polished and the larger ones 6 to 8 inches in diameter. The constituent material is made up largely of various porphyries and other crystalline rocks, reddish and yellow quartzites like those of the Belt formation, numerous agates, pieces of silicified wood, and rarely fossiliferous fragments of Paleozoic limestone. The gravel is generally coarser than that south of Terry, though there is considerable sand in places, as on Belle Prairie, east of the river below Glendive. As the limit of continental glaciation is approached, boulders of granite and blocks of limestone are found scattered over the surface of the gravel and sand, but not intermingled with them. The most southerly glacial boulders were found on Belle Prairie between Cotton and Boxelder Creeks, about 7 miles northeast of Glendive, and about a mile north of Custers Lookout, west of the river. As described below (p. 83), these boulders were evidently dropped from icebergs floating on water ponded in the valley by the front of the great glacier as it lay in the valley north of Intake, long after the development of No. 2 terrace and after the river had cut more than 300 feet below it.

This bench is dissected and worn away to a much greater degree farther down the valley, and below Intake the relations have been somewhat obscured by the overriding glacier and by the deposits of drift which were left. The altitude of No. 2 bench de-

[39] Renick, B. C., Geology and ground-water resources of central and southern Rosebud County, Mont.: U. S. Geol. Survey Water-Supply Paper 600, fig. 3, 1929.

clines from nearly 2,600 feet near Terry to about 2,200 feet west of Sidney—that is, 400 feet in 90 miles, or nearly 4½ feet to the mile. When the Yellowstone was flowing at this altitude in early Pleistocene time it was probably still high enough to traverse the sag in the Coteau du Missouri south of Crosby, N. Dak., about 70 miles northeast of the present mouth of the stream at Mondak, with a fall of nearly 2.5 feet to the mile below Sidney. In other words, it is probable that removal of the thick deposits of later glacial drift from the Coteau du Missouri in northwestern North Dakota would disclose, leading to the broad reentrant in the coteau south of Crosby, a broad sag corresponding in altitude to the grade of the second terrace as projected through the Glendive quadrangle and thence somewhat east of north past Williston, N. Dak., and along the Little Muddy Valley. The point of junction with the upper Missouri River at that time was probably somewhere near or north of the Canadian boundary. In this connection may be noted certain evidence of a valley buried beneath thick drift in the region of Crosby. In a letter to the writer June 26, 1923, Prof. Howard E. Simpson, water geologist of the North Dakota Geological Survey, states that the artesian well of Robert Brevis a few miles north of Crosby, in the SE. ¼ sec. 6, T. 163 N., R. 97 W., was drilled 254 feet through glacial drift to coarse drift gravel, where a strong artesian flow was struck. The altitude of the curb was not stated, but to judge from the altitude along the Souris River about a mile farther north, as indicated on sheet 41 of the international-boundary map, the altitude is not far from 1,925 feet, and that of the gravel at the bottom of the well is about 1,670 feet. The altitude of the upper Missouri River on No. 2 bench in the vicinity of Poplar was about 2,200 feet, the same as that of the Yellowstone at Sidney, and the grade of the upper Missouri below Havre was about 1.75 feet to the mile.

DIVERSION OF THE MISSOURI AND YELLOWSTONE RIVERS IN NORTH DAKOTA

Careful consideration of the relations of the phenomena discussed in this paper leads the writer to the opinion that the diversion of the upper Missouri from a northeasterly course leading to Hudson Bay to a southeasterly course through the Dakotas occurred while yet that stream and the Yellowstone were flowing on the No. 2 bench or second terrace, about 200 feet above their present levels. The upper Missouri, as relocated, cut across to the lower course of the Yellowstone between Mondak and Williston, and at the latter place the waters of the combined streams were deflected to the present course of the Missouri in North Dakota. The diversion was undoubtedly due to the advance of one of the early ice sheets from the Hudson Bay region to the Coteau du Missouri,[90] at either the Nebraskan or the Kansan stage of glaciation.

When the ice sheet blocked the way to the Hudson Bay region all the drainage of the region north and west of the Dakotas was deflected southward and forced to cut across cols between the tributaries of eastward-flowing streams. Until this cutting began to go below the grade of No. 2 bench in Montana, the drainage was retarded and planation at this horizon continued. When the cutting extended below the grade the trenching of No. 2 bench began. Evidently the Missouri was sufficiently intrenched along its new course in North and South Dakota by the end of the Kansan stage of glaciation to maintain that course after the ice had melted away.

LAKE BASINS

No identifiable alluvial benches such as those described above are known to occur in the area between the Yellowstone and Musselshell Rivers, except immediately adjacent to these main streams. There are, however, certain anomalous features which are perhaps to be correlated with the development of the second set of terraces. Such are Lake Basin, Hailstone Basin, and other similar features northwest of Billings. These are described by Hancock[91] as follows:

> The name of this field is very suggestive of its relation to the surrounding region. Although the field is somewhat elevated above the valleys of Yellowstone and Musselshell Rivers, it is nevertheless in the nature of a basin. The Crazy Mountains on the west, the Big Snowy Mountains on the north, and the Bull Mountains and Pryor Range on the east and south present a striking contrast to the relatively low, undrained depression commonly known as Lake Basin. Intimately related to the basin itself are minor features which collectively are the topographic expression of the attitude of the different formations and the marked differences in the degree of resistance they have offered. There are in this field great bodies of shale which alternate with beds of resistant sandstone. Where the overlying sandstones have been eroded the shale is soon worn down to a much lower level, and a basin or broad valley is formed. Such a basin or valley is almost invariably surrounded by a bold escarpment formed by the relatively resistant sandstones. In places streams cut back into the escarpment and masses of sandstone are isolated, which in the course of time give rise to buttes out in the shale area. Battle Butte, a landmark well known throughout this region, is an excellent example.
>
> Lake Basin is a broad depression eroded out of the Bearpaw shale, and the Lennep sandstone, which overlies the shale, forms a rather pronounced escarpment all along the west side of the basin.
>
> Hailstone Basin is structurally a dome in which the Eagle sandstone and the overlying beds have been eroded, and the

[90] Todd, J. E., The Pleistocene history of the Missouri River: Science, new ser., vol. 39, pp. 263–274, 1914; Is the channel of the Missouri River through North Dakota of Tertiary origin?: Geol. Soc. America Bull., vol. 34, pp. 469–493, 1923.

[91] Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: U. S. Geol. Survey Bull. 691, pp. 104–105, 1919.

present surface is well down into the underlying Colorado shale. The basin is limited on the north and east sides by the bold escarpment of Eagle sandstone, and the same condition exists along the south margin of Big Coulee, along the stream leading down toward Painted Robe, and along the north edge of the Yellowstone flats. The south rim of Hailstone Basin, on the contrary, is made up of a great series of fault blocks which erosion has carved into a long chain of low hills without any apparent topographic relationship.

In the small uplift southwest of Broadview the conditions are very different from those of Hailstone Basin. The Eagle sandstone has been removed only in part, and instead of a basin in the underlying shale the sandstone forms the top of a roughly circular hill. This hill, together with the elevated area to the south, separates Lake Basin proper from the broad, depressed area around Comanche.

The anomalous feature of these basins is that they are undrained—that is, their outlets are not deep enough to drain all of the nearly flat bottoms, so that they may formerly have been occupied by large lakes, and if there were a greater rainfall they would now be flooded. There is some question as to the conditions under which the basins were developed and as to how the material was removed to make them basins. As stated by Hancock, the basins lie in belts of soft shale surrounded more or less completely by rims capped with sandstone. Undoubtedly during dry periods the wind has been a potent factor in removing dust from these tracts whenever the soil became bare and dusty. The action of the wind is, however, not so localized as these basins. It seems to the present writer that they may be the result of stream work at times when the Yellowstone River to the south was flowing on No. 1 bench at 3,600 feet or more above the sea—that is, 1,000 feet or more above its present channel west of Billings. Streams tributary to the Yellowstone from the north were not carrying coarse gravel like those from the south, and their lateral meanderings would tend to develop broad plains in the soft shale at altitudes corresponding to the valley plain along the master stream. Once started, the surrounding abrupt inclosing escarpments or rims would continue to recede under the processes of planation described above (p. 13). With the downcutting of the Yellowstone to lower levels the outflowing drainage from these basins would tend to become shifted under the influence of sloping beds of alternating soft and harder strata. It might thus result that as these streams cut down along newer courses the outflow from the basins might not be of sufficient volume to cut down an outlet through the rim to accordant depth, and continued removal of fine silts by the strong winds in dry seasons might lower much of the flat bottoms below the sill of the outlet and so result in an undrained area. The flat bottom of one of these basins in western Yellowstone County is traversed by the Great Northern Railway between Acton and Broadview. This plain has an extent of more than 60 square miles. The village of Comanche, near its center, is 3,740 feet above sea level. This is not far from what was probably the original level of No. 1 bench in the region of Billings. Lake Basin (see Stillwater topographic map), in northern Stillwater County, is traversed by a branch of the Northern Pacific Railway. The terminus in 1921 was at the village of Rapelje, at about 4,100 feet above sea level. Wheat Basin is north of Big Lake, and the village of Molt (formerly Stickley post office), about 5 miles east of the lake, at 3,950 feet (barometric), is located at a sag which was probably the former outlet of the basin and through which the railway now runs. The sharp newer-cut gorge of Canyon Creek passes within a mile of this outlet on its way down to the Yellowstone Valley. The altitude of the bottom of Lake Basin is about the same as that of No. 2 bench on the Yellowstone at Columbus, about 15 miles south. The rim on the southwest side of Lake Basin rises with steep marginal slope and in places bluffs 800 to 1,000 feet or more above the nearly flat bottom of the basin. This ridge is the southeastward extension of the Cayuse Hills east of Melville.

NO. 3 BENCH

RELATIONS TO GLACIAL DRIFT

In many places throughout the region here described there is a well-marked gravel-capped terrace or bench between the second set of terraces and the present valley bottoms. This may be designated No. 3 bench or terrace. The relations indicate that the completion of the second set of terraces was followed by a well-defined stage of downcutting of the streams throughout the region, and this in turn was followed by lateral planation and deposition of river gravel on the broad valley bottoms thus developed. Away from the mountains this bench is generally 100 to 200 feet or more below the second benches and is confined between the main lines of bluffs bordering the inner valleys. The relations seem to indicate a period of regional uplift after the formation of the second benches, causing active downcutting by the streams as the result of increased gradients, followed by a sufficiently long period of stillstand to permit lateral planation to broaden the valley bottoms to widths ranging from 1 mile to several miles. Contemporaneously smaller tributaries actively dissected older benches and the bordering uplands. There is conclusive evidence that No. 3 bench was completed as early as the oncoming of the Wisconsin stage of glaciation.

It now seems probable (see pp. 47–48) that Carlow Flat, between Cut Bank and Browning, in Glacier County, is somewhat older than was formerly supposed and is not to be regarded as representative of the third set of terraces.[92] It is now correlated with the broad bench north of Dupuyer and with the lower

[92] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924.

level of the second set of terraces throughout the region. The third set of terraces is probably more nearly represented by the broad bottom of Flat Coulee, the channel which the Two Medicine River cut 100 to 200 feet through Carlow Flat terrace and which it later abandoned, when the Two Medicine Glacier extended out onto the plains. The terminal moraine of this glacier extends down the side slopes of Flat Coulee and across its broad bottom, showing clearly that the coulee, as well as Carlow Flat, is of pre-Wisconsin age. Spring Creek has now cut a narrow gorge in the bottom of Flat Coulee. This bottom is about 200 feet above Cut Bank Creek, to the east, and the Two Medicine River, to the south. A similar broad-bottomed coulee was cut below Carlow Flat on the north. This is traversed for several miles by the Great Northern Railway and the Roosevelt Highway, between Bombay and Carlow sidings, where it lies 100 feet or more below the top of the terrace and the crest of the moraine on the south. To the third set of terraces also belong Greasewood Flat, north of Browning, and the broad gravelly flat bordering Badger Creek where crossed by the Park to Park Highway at Piegan. The broad gravelly flat bordering Birch Creek is regarded by Eugene Stebinger as No. 3 bench, and he states in his notes that it might be mistaken for outwash of the Wisconsin stage.[93] South of Birch Creek the moraine extends across No. 3 bench and up the 200-foot slope to No. 2 bench, about 7 miles northwest of Dupuyer. No. 3 bench extends eastward, under the name Birch Creek Flats, to the west limit of the Keewatin glacial drift of Wisconsin age. It seems probable also that the great irrigated gravelly flat north of Choteau, on which stand the villages of Bynum, Agawam, and Farmington, in Teton County,[94] is also to be correlated with No. 3 bench. This flat is crossed by branches of the Great Northern and the Chicago, Milwaukee, St. Paul & Pacific Railways, and a few miles east of the latter the bench passes under the terminal moraine of the Keewatin drift. It is reported that a deep well drilled by the California Co. near Agawam, in the NE. ¼ sec. 25, T. 26 N., R. 5 W., passed through 40 feet of unconsolidated limestone gravel before entering the underlying shale. The altitudes at Farmington and Agawam are 3,889 and 3,800 feet, respectively, and at Bynum 3,970 feet (Great Northern Railway). The altitude on No. 1 bench at Pendroy, 7 to 8 miles north of Bynum, is 4,264 feet (Great Northern Railway). The Teton River has cut its broad-bottomed valley in the vicinity of Choteau to a depth of 100 feet or more below this broad No. 3 bench.

[93] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, p. 46, 1906.

[94] Fisher, C. A., Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, pl. 1 (shown as Burton Bench), 1909.

In the vicinity of Gilman and Augusta the relations of the terminal moraines of the Sun River and Smith Creek Glaciers are such as to show that the second set of terraces is older than the drift deposited by the mountain glaciers at their greatest extension, which is referred to the Wisconsin stage of glaciation. It is not so clear, however, that the broad terrace bordering the outer moraine in the vicinity of Augusta and Gilman is older than the moraine on the Sun River north of Gilman. The relations seem to indicate that the terrace is composed of outwash from the moraine. It also seems probable that the Dearborn River was flowing eastward from the mouth of its canyon in the mountains to and down the broad valley of Flat Creek and not in its present narrow 300-foot gorge, 13 miles south of Augusta, when No. 3 bench was being formed.

North of Gilman, in T. 21 N., R. 6 W., the inner valley of the Sun River is cut to a depth of about 100 feet below No. 3 bench, which is half a mile to a mile wide on each side above the gorge. The terminal moraine of the Sun River Glacier descends the eroded slope below No. 2 bench on both the north and the south and crosses the broad outer valley for nearly 3 miles on No. 3 bench. The relations of the moraine to the second bench are clearly visible from the Park to Park Highway and the main road north of Gilman. The Sun River terraces were not mapped in detail from Gilman eastward to Great Falls, but, as seen by the writer on two trips along the valley, it appears that No. 3 bench is well preserved on the north side of the river eastward nearly to Reibeling. There are also some narrow remnants on the south side, and the upper irrigation ditch west of Simms is on one of them. No. 3 bench appears to have been developed about the north side of Floweree Butte along Big Coulee. Here there is 10 to 15 feet of stratified gravel overlying the shale beneath the bench. The Chicago, Milwaukee, St. Paul & Pacific Railway at and near Ashuelot station is on a higher or No. 2 bench, described above (p. 47). Near and east of Great Falls the relations of the third terrace are obscured by erosion, by the shifting of the course of the Missouri River, and by the deposition of the Keewatin glacial drift.

It seems probable that some at least of the cut-off and abandoned parts of the inner valley of the old Missouri River are to be correlated with the development of No. 3 bench, and that as erosion proceeded below this horizon local conditions resulted in the stream's diversion. One of these abandoned channels is traversed by the irrigation canals east of Malta and by the Great Northern Railway between Malta and Beaver Creek east of Lake Bowdoin. This old, partly drift-filled valley is 3 to 5 miles in width. The conditions attending its abandonment are described below (p. 112).

The Great Northern Railway between the mouth of the Milk River and Wolf Point runs in places on remnants of a broad terrace extending 1 to 2 miles north of the flood plain of the Missouri. (See Nashua, Frazer, Oswego, Chelsea, and Wolf Point topographic maps.) This terrace rises gradually westward, reaching about 2,140 feet above sea level, or 120 feet above the river, west of Frazer. With this is probably to be correlated the abandoned former valley of Wolf Creek about 4 miles west of Wolf Point, in secs. 1, 12, and 13, T. 27 N., R. 46 E. This is the continuation of No. 3 bench farther north along the west side of this creek and 60 to 80 feet above it. Another correlative is the abandoned valley 4 miles long which is cut through behind the ridge south of the river opposite Wolf Point and which leads from the Sand Creek Valley to the Fort Charles cut-off.

A narrow terrace borders the foot of the bluff southeast of Wolf Point but it is mostly cut away between that place and Poplar. At Poplar the terrace appears to be represented by the ridge on which the village stands, and this is the correlative of No. 3 bench farther north along the Poplar River Valley. When this was being developed the Poplar River had abandoned and cut below its former outlet to the Tertiary Missouri River Valley in the northeastern part of the Poplar quadrangle.

Between Brockton and Culbertson Big Muddy Creek joins the Missouri. This stream occupies part of a continuous broad, flat-bottomed valley which, as described below (p. 129), was, at one or more stages of glaciation, an outlet for water of the Saskatchewan River when ponded by the glacial margins. In this valley in southern Saskatchewan lie Big Muddy Lake and Willowbunch Lake, in the Bengough district, and Lake of the Rivers and probably other lakes farther northwest in Moose Jaw County. In Sheridan and Roosevelt Counties, Mont., this valley cuts directly across the broad Tertiary valley of the Missouri River. There are remnants of a well-marked gravel-covered cut terrace in several places along the Big Muddy Valley in Sheridan County, but the deposits have not been examined in sufficient detail to make sure whether or not the gravel is of nonglacial origin. It is suggested that this terrace may correspond to No. 3 bench on the Missouri and Yellowstone Rivers. Near Redstone the terrace is 50 feet or more above the valley bottom. A similar broad terrace remnant was crossed about 5 miles southeast of Redstone and other remnants southeast of Plentywood, 2 miles south of Antelope, and also at Homestead.

From Culbertson to Lakeside the Great Northern Railway traverses an abandoned part of the Missouri River Valley.[95] (See pl. 1.) This is also occupied in part by Little Muddy Creek and its tributaries. Altitudes along this channel, which is nearly 2 miles in width and may correspond with No. 3 bench, are at Culbertson, 1,921 feet; Lanark, 1,985 feet; Bainville, 1,960 feet; Lakeside, 1,910 feet (Great Northern Railway).

NO. 3 BENCH IN NORTH DAKOTA

Other similar terrace remnants and abandoned channels possibly to be correlated with No. 3 bench occur in North Dakota. These have been described by Wilder,[96] together with the possibilities of their irrigation. The Nesson-Hofflund Flats are shown in part on the Ray topographic map. Here a flat 2 to 3 miles in width and 80 to 100 feet above the Missouri Valley bottom is partly separated from the flood plain by one or two low hills. Back of the bench is a curving line of dissected bluffs and steep slopes rising 200 to 300 feet to the smooth upland. A. J. Collier[97] states that lignite is in place below the edge of the bench south of Nesson post office. Shale and lignite are also exposed below the gravel covering a remnant of a similar terrace on the south side of the valley near the mouth of Tobacco Garden Creek.

From these occurrences it would seem that the valley here was not cut down to the present river level before this terrace was formed. Wilder[98] also refers to an abandoned channel of the Missouri between the mouths of Little Knife and Shell Creeks in the Fort Berthold Indian Reservation. The upper end of the valley is said to be about 140 feet above the river, and below is a terrace 80 feet above the stream. The old channel is separated from the present course of the river by a broad ridge 10 miles or so in length. This channel has also been described by Wood,[99] Smith,[1] and Pishel.[2]

Terraces nearly opposite the mouth of the Little Missouri River and farther east at the old Indian agency in T. 147 N., R. 87 W., are 20 to 80 feet above the stream. The Fort Stevenson Flats are 30 to 70 feet above the river. (See Garrison topographic map.)

It should be noted that not all the stream deposits in the abandoned channels or on the cut terraces cited above are known to be either pre-Iowan or not glacial

[95] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, pls. 26, 27, 1912.

[96] Wilder, F. A., The lignite of North Dakota and its relation to irrigation: U. S. Geol. Survey Water-Supply Paper 117, pls. 2–4, 6, 8, 1905.

[97] Personal communication.

[98] Idem, p. 35, pl. 6.

[99] Wood, L. H., North Dakota Geol. Survey Second Bienn. Rept., pp. 102–104, 1902.

[1] Smith, C. D., The Fort Berthold Indian Reservation lignite field, N. Dak.: U. S. Geol. Survey Bull. 381, p. 31, 1910.

[2] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, N. Dak.: U. S. Geol. Survey Bull. 471, p. 171, 1912.

outwash. Further study may show that at least some of them are not to be correlated with No. 3 bench.

NO. 3 BENCH IN JUDITH RIVER BASIN AND MUSSELSHELL VALLEY

Some tracts of No. 3 bench border streams in the Judith River Basin.[8] The village of Stanford stands on one of these which border Wolf Creek. This is about 150 feet lower than No. 2 bench, to the west.

In T. 17 N., R. 16 E., the main road in the valley of Warm Spring Creek is on No. 2 bench westward nearly to Deerfield, at 3,700 feet above sea level. The road then runs down a short, abrupt 100-foot slope to No. 3 bench, which extends far to the south and west to the Judith River gorge. Both of these benches are irrigated and produce fine crops of grain. It appears that lateral planation was not nearly so extensive in this basin at the third stage as when No. 2 bench was being formed. The Judith River and most of its tributaries, at least in their lower courses, now flow in sharp, narrow gorges cut 100 to several hundred feet below No. 3 bench.

There are here and there some traces of a third gravel terrace bordering the Musselshell River and its tributaries, but in most places seen the rather broad plains between No. 2 bench and the immediate flood plains are gently undulating erosional surfaces not covered with gravel. Harlowton is built partly on a third terrace, and other remnants border the river farther west, as near Two Dot and Martinsdale. West of Groveland station there is 20 to 25 feet of coarse cobblestone gravel exposed near the railway in an excavation in the edge of a terrace. This terrace extends southward up the Cottonwood Creek Valley and heads in the Crazy Mountains.

NO. 3 BENCH IN THE YELLOWSTONE BASIN

No. 3 bench appears to be better developed or better preserved along the Yellowstone River and its tributaries than on the Missouri River and its other tributaries. The relations to the glacial moraines above Livingston of what in reality may be the No. 3 stream terrace are discussed on page 123. The automobile road from Livingston to Chico Springs, on the east side of the valley, runs partly on and partly below this broad gravel terrace. This is also traversed by the road on the west side of the valley part of the way below Eightmile Creek. Near this stream and Elbow Creek the terrace either merges with the outer moraine or emerges from under it. Here the terrace is more than 100 feet above the river. Near Emigrant a ledge of basalt projects from the bluff below the terrace and above the roadway. Gravel is exposed below the level of the basalt but was not observed to extend under the lava. Southwest of the village the basalt caps a ridge above the level of the terrace and 150 to 200 feet above the road, but no exposure of the underlying material was seen. A mile or more farther southwest, at the railway spur where material has been excavated, a sheet of basalt 5 to 20 feet thick with some agglomerate at its base overlies sand and gravel. The smoothly rounded pebbles of the gravel range from less than 1 inch to 1 foot in diameter and consist of quartzite, granite, porphyry, and other igneous rocks. At 5 or 6 miles above Emigrant upturned and eroded cream-colored clay, of supposed Tertiary age, composes the conspicuous White Cliffs, rising above the east bank of the river. (See pl. 24 *B*.) This clay is unconformably overlain by 80 feet or more of very coarse, smoothly worn stream gravel. Above the gravel is a sheet of columnar basalt which caps the broad plateau or bench 250 feet or more above the river and which extends eastward a mile or more to the sag in which lies Duck Lake and southward about 5 miles opposite Point of Rocks. The relations, though somewhat obscured by erosion and by overlying glacial drift, strongly suggest that the broad gravel terrace farther down the valley, instead of being glacial outwash, is older than the moraines of the Wisconsin stage and is the continuation of the thick deposit of stream gravel which underlies the basalt flow. These are tentatively correlated with the No. 3 set of terraces and benches. The basalt was probably originally continuous along the valley for at least 11 miles above Emigrant. It is not known that it ever extended farther up or down the valley.

Two lower terraces, about 25 and 50 feet above the river, border the stream near Miner station and through much of the distance below Yankee Jim Canyon.

No. 3 bench spreads out broadly on the east side of the river opposite Livingston. Here it consists of great coalescent alluvial fans heading at the mouths of the gulches which dissect the mountain mass below Livingston Peak. A narrow strip of this terrace borders the hill north of the city, but Livingston itself stands on a lower terrace.

The lower course of the Boulder River for several miles south of Big Timber is bordered on the east by a third gravel terrace. Its correlative in the Yellowstone Valley is traversed for miles by the Yellowstone Trail. This is above the railway on the south side of the valley. Near Columbus the third terrace is well developed both north and south of the river. The gravel exposed west of Columbus near Bensons Bluff, though opposite the mouth of the Stillwater River, differs from the bench gravel along that stream and its tributaries in containing more quartzite and

[8] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, pl. 1, 1909. Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, pl. 1, 1909.

porphyry and less granitic rock. The terrace in this vicinity is 50 to 100 feet above the river. It is well defined at Luther post office on Red Lodge Creek, in T. 6 S., R. 19 E., also below Red Lodge on Rock Creek. It spreads out broadly between Joliet, on Rock Creek, and Edgar, on Clark Fork.

Farther south up Clark Fork traces of a No. 3 bench were noted only here and here until the bridge near Allen's ranch, 2 miles north of the Wyoming-Montana line was reached. Extending thence southwestward much if not all of the distance to the mountain front is a terrace of bouldery gravel. Just north of Clark post office, Wyo., it is 4,309 feet above sea level, or 30 feet above the broad flat on which the buildings stand. The flat rises westward to the glacial terminal moraine. It may in reality pass under the moraine and be represented by the terrace at the mouth of the Clark Fork Canyon. The flat gravelly terrace in front of the moraine appears not to be simply an outwash plain, but the presence of the big boulders scattered upon it and also on small hills, erosion remnants rising above it, suggests that some at least of the pebbles and boulders on the plain have been let down by erosion from a higher terrace of which there are now but few remnants in this vicinity. Near the bridge south of Clark post office the stream has cut 100 feet below No. 3 terrace. For miles southward from the stream the Cody road, or Black and White Trail, runs on a part of this terrace, known as Chapman Bench, on the east side of Pat O'Hara Creek.

For some distance below the confluence of Clark Fork with the Yellowstone River No. 3 bench is not well developed or is not much above the general flat along the river. It is through this same part that No. 2 bench is also relatively low (p. 53). The Northern Pacific Railway runs mostly on the gently sloping flat just below the bluff that rises to No. 2 bench. There is a low terrace near the village of Pompeys Pillar, and as the valley deepens eastward below No. 2 bench, No. 3 bench becomes somewhat more distinct.

On the Big Horn River below the lower canyon in Montana the No. 3 terrace, so far as seen, is not clearly distinct from the broad valley floor except for 5 or 6 miles just below the mouth of the canyon. Here there is a broad terrace of limestone gravel over shale 75 to 100 feet above the river. The irrigation canal is excavated along the eroded slope below the north margin of this terrace on which was the site of old Fort C. F. Smith. (See topographic map of St. Xavier quadrangle.)

The Yellowstone River throughout its course is now deepening and broadening its flat below this No. 3 terrace, so that most of the valley floor is not a flood plain which is periodically submerged but a plain 1 to 3 miles wide, the parts of which on one or both sides slope gently toward the crests of the stream banks from what was probably the level of No. 3 terrace at the outer margin. On this valley floor are extensive irrigated tracts with finely improved farms producing alfalfa, small grains, and sugar beets. This extends for some distance east of Hysham on the south side of the Northern Pacific Railway and of the valley. At Sanders it is 30 to 40 feet above the railway, and its edge is followed by the irrigation canal. No. 2 bench is 140 feet higher. No. 3 bench is well marked at the cemetery 1 mile east of Forsyth. Doubtless there are other remnants which can not be seen from the Yellowstone Trail. One of these is near Horton, about 100 feet below No. 2 bench, on which is the Northern Pacific Railway gravel pit. From the Powder River down to the mouth of the Yellowstone there appears to be little chance of confusion of the second and third terraces. Two beds of lignite are exposed in the bluff below the lower bench near the Chicago, Milwaukee, St. Paul & Pacific Railway Bridge west of Terry. It is important to note that here and at all other places examined, both upstream and downstream, at least as far as Intake, the evidence is conclusive that No. 3 bench, like the benches at higher levels, is a cut terrace merely veneered with gravel. At no place does it appear that the Yellowstone River had previously cut down to lower levels and then refilled its valley to the height of No. 3 terrace. Further consideration is given to this below (p. 64). The town of Terry and both railways are on No. 3 terrace, which is 50 feet or more above the river and nearly 300 feet below No. 2 terrace.

At 8 miles east of Terry the Yellowstone Trail runs up again to No. 3 bench. On this the Chicago, Milwaukee, St. Paul & Pacific Railway swings to the southeast and runs up the valley of O'Fallon Creek. The village of Fallon is on the lower part of this sloping terrace at 2,231 feet above sea level. East of Fallon the Yellowstone Trail leaves the river and runs eastward up 240 to 250 feet onto No. 2 bench. The Red Trail crosses the river below Fallon and runs down the west side of the valley to Glendive, in places on No. 3 bench and in places on gently sloping surfaces eroded to somewhat lower levels. Near and below Glendive the Sidney branch of the Northern Pacific Railway is graded in many places along the foot or face of the low bluff below the edge of No. 3 terrace. Wherever examined either shale or sandstone is in place beneath the bench gravel, showing that this is a cut terrace. The main road down the valley on the west side is in places on this third terrace and in places on the valley bottom, 50 feet or more below.

Just west of Glendive the altitude near the edge of the terrace is 2,120 feet. Excavations at this place expose 10 feet of gray clay, overlying 10 feet of rusty stratified gravel containing streaks of sand. The pebbles are mostly 2 to 3 inches or less in diameter, but some cobblestones 6 to 10 inches long occur. Scratches seen on some of the stones resemble glacial striae, but possibly they were produced by river ice. North of Burns there appear to be some intermediate bench levels between the main lower terrace and No. 2 bench, to the west. Near the south line of T. 21 N., southwest of Crane, the terrace passes below the grade of the diversion canal, and thence northward it is irrigated. Near Sidney the terrace is less well defined and the surface drops to the flat bordering the river by a series of low steps.

The following description of that part of the terraced valley bottom in North Dakota is given by Wilder:[4]

> Above the flood plain, which is covered with a dense growth of willows, is a wooded bench from 10 to 15 feet above high water, where large cottonwoods flourish. Its extent may equal 4,000 or 5,000 acres. Ten feet above this and 20 feet above the river at high water is the edge of a beautiful and extensive grassed terrace, which rises gradually for 2 miles to the foot of the bluffs and which has an area of about 15,000 acres, below a contour line drawn 80 feet above the river. It is not cut up by ravines or gullies, and a trench can be carried along the 80-foot contour with but few flumes. With such an initial head, water can be taken to almost any point on the flat.

The present writer has no data showing whether or not in the lower stretches the valley was formerly cut down to lower levels and subsequently refilled. It is probable, however, that there has been some refilling below Sidney corresponding with the refilling that is known to have occurred along the Missouri River. The depth shown is, however, not very great.

MISSOURI VALLEY FILLING IN NORTH DAKOTA

Herald[5] cites the following data bearing on the depth of erosion and refilling along the Missouri near and below the mouth of the Yellowstone River:

> Missouri River and Muddy Creek Valleys are filled with alluvium. The thickness of this filling is not well known, but a vertical exposure of the river bank near Trenton shows 54 feet of alluvium. It is probable that the maximum thickness in the field is but little greater. * * *
>
> That Missouri River has not eroded far below its present channel is indicated by the following drill logs, which were furnished by the United States Reclamation Service. These borings were made in testing for a foundation for a pumping site (about a mile southwest of Buford, N. Dak.). The holes are all shallow and show very little lignite, but they are of value in proving that Fort Union strata occur in place at shallow depths under the [north ⅓ of the] alluvium-covered valley [flat].

List of United States Reclamation Service test borings for pumping-site foundation in secs. 8, 16, and 17, T. 152 N., R. 104 W.

No. of hole	Location [a]	Total depth (feet)	Surface altitude (feet)
1	500 feet north and 300 feet west of A	33	1,902
2	450 feet west of A	33	1,886
3	About 700 feet south and about 500 feet west of A	27	1,873
4	About 900 feet south and about 1,200 feet west of A	46	1,875
5	550 feet west of A	77	1,908
6	400 feet north and 30 feet west of A	76	1,907
7	700 feet west of A	51	1,886
8	40 feet west of A	53	1,886
9	Center of NW. ¼ SE. ¼ sec. 16	40	

[a] Location of point A is center of south line of SE. ¼ sec. 8.

Logs of United States Reclamation Service test borings for pumping-site foundation in secs. 8, 16, and 17, T. 152 N., R. 104 W.

	Ft.	in.
Hole No. 1		
Gumbo	9	
Sand and pebbles	4	
Sand	5	2
Sand, fine	15	3
	33	5
Hole No. 2		
Gumbo	9	
Sand	23	
Sand and pebbles	1	
	33	
Hole No. 3		
Gumbo, sandy	1	
Gumbo	7	
Sand	10	
Quicksand	9	
	27	
Hole No. 4		
Sand	5	
Gumbo	14	
Sand, fine	6	
Clay	1	
Sand	20	7
	46	7
Hole No. 5		
Sand	4	
Gumbo	8	
Sand	3	
Clay	5	
Gravel	23	
Clay	23	
Sandstone, soft	11	
	77	
Hole No. 6		
Gumbo	19	
Gravel	22	
Quicksand	16	
Sandstone, soft	10	
	67	
Hole No. 7		
Sand	1	7
Gumbo	7	5
Gumbo and sand	5	
Quicksand	16	
Sand	4	
Clay and sand	15	
Lignite		11
Sand, coarse	1	1
	51	
Hole No. 8		
Gumbo	9	
Sand, fine	11	
Quicksand	7	7
Sand, coarse	2	5
Lignite	1	
Pebbles	1	
Boulder	1	7
Sand, coarse	11	
Quicksand	8	5
	53	
Hole No. 9		
Sand	31	
Boulders	4	6
Lignite	1	
Sand	3	6
	40	

It is possible that the lignitic material in holes 7, 8, and 9 is not in place but is washed over and redeposited material such as is occasionally found in stream deposits. There is a distance of about a mile between the locations of these drill holes and the side of the valley to the southwest, and the buried channel may be deeper in this interval.

[4] Wilder, F. A., The lignite of North Dakota and its relation to irrigation: U. S. Geol. Survey Water-Supply Paper 117, p. 27, 1905.
[5] Herald, F. A., The Williston lignite field, Williams County, N. Dak.: U. S. Geol. Survey Bull. 531, pp. 96, 156–157, 1913.

Herald[6] gives the following logs of United States Reclamation Service drill holes southeast of Williston, one in the northern part of the NW. ¼ sec. 4, T. 153 N., R. 100 W., and one in the western part of the SE. ¼ sec. 4, both on the Missouri bottom land.

Log of drill hole in NW. ¼ sec. 4

	Feet
Clay	50
Gravel and sand	4
Clay and sand	6
Gravel	5
Clay	13
Sandstone	7
Clay	5
Sandstone	10
	100

Log of drill hole in SE. ¼ sec. 4

	Feet
Gravel, sandy	10
Sand (trace of lignite)	16
Sand	12
Sand, clay, and gravel	3
Clay, sandy	7
	48

The greater part of the material penetrated is regarded as alluvium.

Borings made by the Great Northern Railway in the channel of the Missouri River 3 miles west of Elbowoods and a few miles below the mouth of the Little Missouri River, in T. 147 N., R. 101 W., northeastern Dunn County, formerly in the Fort Berthold Indian Reservation, show the presence of quicksand and river mud to a depth of 60 feet.

GRAVEL UNDERLYING OLDER KEEWATIN TILL

PRE-IOWAN OR PRE-ILLINOIAN (?) GRAVEL IN SOUTHERN ALBERTA

Probably few if any of the streams of southern Alberta are flowing along exactly the same courses as they did prior to deposition of the glacial drift, but there are places where the streams appear to cut across old filled channels. In some of these places deposits of the Wisconsin glaciers are underlain by till of an earlier stage of glaciation, and here and there this earlier till is in turn underlain by deposits of coarse quartzite stream gravel derived entirely from the mountains and showing no evidence of glaciation. Some of these deposits were described by Dawson and McConnell[7] under the name "Saskatchewan gravel." In the exposure north of Lethbridge, described on page 73 (fig. 5), there is 10 to 15 feet of quartzite gravel about 100 feet above the stream, overlying the eroded surface of the Cretaceous shale and overlain by the lower glacial till (Iowan or Illinoian ?). This gravel may perhaps represent either the Sangamon or the Yarmouth stage of deglaciation as recorded in Illinois and in Iowa. In view of the relations of the high-level and low-level deposits described above, it does not seem probable to the writer that the Belly River was flowing at so low a level in pre-Pleistocene time. It is therefore inferred that this gravel has either been derived directly from the mountains, as the result of the deepening of the mountain gorges from the horizon of No. 2 bench to that of No. 3 bench and lower levels, or that the gravel has been let down by erosion from the former and older deposits on the higher levels of the plains and redeposited by the streams.

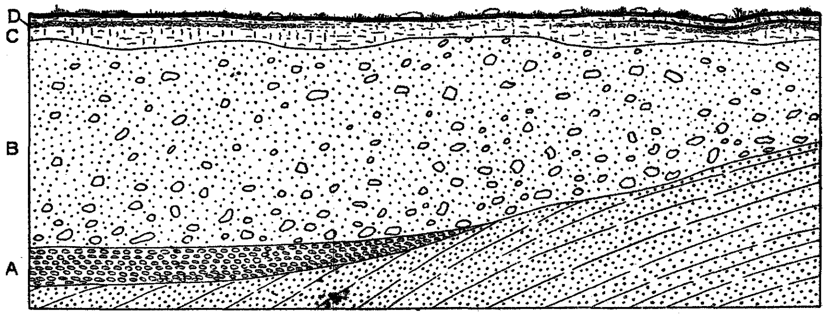


FIGURE 2.—Section on St. Mary River 1 mile south of Kimball, Alberta. A, Quartzite gravel ("Saskatchewan"), interglacial (?), 0 to 15 feet, overlying sandstone; B, glacial till of Keewatin glacier, 50 to 100 feet; C, loesslike clay, 10 feet; D, gravel overlain by a few feet of soil

At the other places in southern Alberta where both Wisconsin and pre-Wisconsin tills of the Keewatin ice sheet have been observed in the same exposure, either the streams have not cut deep enough to uncover the base of the lower till (see p. 66) or the lower till immediately overlies the eroded surface of the Tertiary or Cretaceous rocks, with no intervening gravel. The latter condition might occur at any place where the present stream was neither following nor cutting across an old buried stream channel. At several places similar quartzite gravel was seen immediately overlying Cretaceous or Tertiary rocks and overlain by Keewatin till, but there is apparently no way of determining whether the one till deposit exposed is of Wisconsin or pre-Wisconsin age. Such a condition was noted 40 miles south of Lethbridge, in the St. Mary Valley, about 1 mile above Kimball (fig. 2), where 0 to 15 feet of quartzite gravel is overlain by 50 to 100 feet of till from the Keewatin ice sheet, which apparently forms a single

[6] Herald, F. A., The Williston lignite field, Williams County, N. Dak.: U. S. Geol. Survey Bull. 531, p. 137, 1913.

[7] Dawson, G. M., and McConnell, R. G., Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains: Geol. Soc. America Bull., vol. 7, pp. 35–66, 1895.

sheet of drift. As there is nothing here to show whether the till is the upper or the lower till, it is regarded as Wisconsin. The bed of gravel pinches out midway in the length of this exposure against the rising surface of the underlying upturned and eroded sandstone, as if it had been deposited only in the bottom of a former channel.

At the bend nearly opposite Sloan's ranch, a few miles farther south, 30 feet of coarse "quartzite gravel" lies on the eroded surface of the Cretaceous rocks and is overlain by 10 to 12 feet of till containing scattered pebbles of pre-Cambrian crystalline rocks and itself overlain by a 5-foot bed of gravel containing pebbles of pre-Cambrian rocks. The only evidence of mountain glaciation noted this far north in this valley consisted of several 3-foot blocks of reddish argillite in a ravine between the last two points mentioned.

Farther southwest, upstream, another exposure shows 10 feet of quartzite gravel lying on the eroded surface of the Cretaceous sandstone and overlain by till containing pebbles of pre-Cambrian crystalline rocks and above this laminated sandy clay containing a few pebbles from the Rocky Mountains and pebbles of pre-Cambrian crystalline rocks from the northeast.

At a point on the upper Belly River about 27 miles south of Macleod, in T. 5 N., R. 26 W., a fine exposure of the quartzite gravel was seen.

Deposits on Belly River 27 miles south of Macleod, Alberta

	Feet
Dark soil	1–2
Laminated gray silt	8–10
Solid buff to gray clayey till of the Keewatin ice sheet; pebbles mostly from the Rocky Mountains, but pebbles of pre-Cambrian crystalline rocks from the northeast scattered throughout	10–12
Stratified, waterworn gravel ("Saskatchewan," interglacial?); pebbles exclusively quartzite and other rocks from the Rocky Mountains, ranging from a fraction of an inch to 6 inches in diameter. Partly cemented fine material fills the interstices, and streaks of cross-bedded sand occur in places. The upper 1 foot of the gravel is oxidized to a dull orange tint, as if marking a zone of weathering. Bottom not exposed	15

At none of the sections examined farther up this stream was the gravel exposed. In fact, although the stream has cut 60 to 75 feet in drift below the level of the plain, at several places examined within a few miles of Hillspring village, in T. 4 N., R. 27 W., it has not yet reached the bottom of the till of the Keewatin ice sheet except at one place, where it swings against the side slope of the former valley. Farther up the valley, where the stream cuts through the terminal moraine of the Keewatin glacier and beyond this moraine, the stream at many places exposes the Cretaceous sandstone and shale underlying the drift, but nowhere is quartzite gravel present. Neither was the quartzite gravel found intercalated between the drift and the Cretaceous rocks at the exposures examined on the Drywood Fork of the Waterton River. No sections were examined on the Waterton River except in the vicinity of its confluence with the Belly River.

At most of the exposures examined on the South Fork of the Oldman River west of Pincher, in Ts. 7 and 8 N., R. 30 W., till rests directly on the Tertiary (?) sandstone or shale with no intervening quartzite gravel.

PRE-IOWAN OR PRE-ILLINOIAN (?) GRAVEL IN MONTANA

From the above descriptions it is clear that there is a deposit of stream gravel older than the lower till of the Keewatin ice sheet. The quartzite gravel underlying Keewatin till at the other places may be of the same age or later (pre-Wisconsin).

West of the point where the Chicago, Milwaukee, St. Paul & Pacific Railway crosses Highwood Creek near Highwood, Cascade County, Mont., several cuts expose the following section:

Section on Chicago, Milwaukee, St. Paul & Pacific Railway west of Highwood

	Feet
4. Dull pebbly clay, glacial till	20–40
3. Sand, about	5
2. Sand and coarse gravel	10–15
1. Black shale.	

At one point the sand (No. 3) was replaced by 2 feet of laminated clay. It is probable that the gravel (No. 2) is a preglacial stream deposit derived from the Highwood Mountains, inasmuch as no Belt (?) quartzite or granite pebbles were found in it by the writer, although plenty of the former and a few of the latter were noted in the overlying glacial till.

Railway cuts on the upper part of the bluff west of Fort Benton expose the following series of deposits as noted by the writer in 1923:

Glacial and associated deposits west of Fort Benton

	Feet
6. Recent: Dull gray, wind-blown silt which forms a small hill rising above the upland, about	50
5. Wisconsin stage: Glacial gravel composed principally of quartzite pebbles but with intermingled granitic pebbles from Canada, about	10
4. Peorian (?) stage: Fine buff loesslike sandy clay with some small pebbles in the lower part, mostly finely laminated, and rippled like wind-blown silt	20–30
3. Iowan or Illinoian (?) stage: Unstratified and semi-stratified buff sandy clay containing granitic and other pebbles from Canada. Probably glacial drift	10–12
2. Nonglacial: Well-rounded stream gravel; pebbles mostly quartzite, none granitic	8–10
1. Cretaceous: Colorado shale comprising the lower two-thirds of the bluff along the river.	

Gravel similar to No. 2 is exposed beneath 40 to 50 feet of glacial till near the tops of the bluffs both north and south of Fort Benton.

Bluffs along the lower few miles of the Teton River, near its junction with the Missouri River, show in places a bed of gravel lying on the eroded surface of the shale and overlain by glacial till, which is as much as 100 feet thick. It seems probable that much of the till in these bluffs is of pre-Wisconsin (Iowan or Illinoian?) age and that the gravel may be correlated with that cited above, though no intercalated soil or weathered zone separating an upper from a lower till has been found in these sections, either by Calhoun, Stebinger, or the present writer.

GRAVEL UNDERLYING IOWAN OR ILLINOIAN (?) TILL OF MOUNTAIN GLACIERS

Other exposures than those described above have been observed where the quartzite gravel is overlain by drift of the mountain glaciers, and this in turn by drift of the Keewatin ice. The question of the age relations of the tills where this overlap occurs is discussed below (p. 105).

Dawson[8] describes three sections where similar gravel underlies the mountain till—one at a point on the North Fork of the Old Man River, 2 miles north of its junction with the Middle Fork; a second on the South Fork of this stream about 12 miles from the mountains; and a third still nearer the mountains on Mill Creek. Concerning these he writes:

> The two last-mentioned localities are within the limit of the country characterized by moraines, evidently due to local glaciers from the Rocky Mountains, and the indurated boulder clay of the Mill Creek section is believed, like the moraines, to be a deposit of these glaciers. The lower gravels in this case and in that of Pincher Creek are obviously due to preglacial streams flowing from the mountains, and, although the name Saskatchewan gravels may be applied to them, they here evidently antedate the eastern gravelly representative of the Rocky Mountains or earliest boulder clay. Farther to the east, where this boulder clay gradually passes into such gravels, there is no means of distinguishing between wholly preglacial beds and those which may have been formed during the main period of the Rocky Mountain glaciers. Many exposures of the Saskatchewan gravels may include both, and this without necessitating the supposition of any great chronologic break.

At the international boundary the following section was observed by the present writer in 1912 and reexamined in 1920:

Deposits on St. Mary River at international boundary

	Feet
Gray clayey till of Keewatin ice sheet; pebbles mostly from the Rocky Mountains, but with a small percentage of pebbles of pre-Cambrian crystalline rocks from the northeast (Wisconsin stage)	20
Gray till; pebbles so far as noted all from the Rocky Mountains (mountain drift)	20
Quartzite gravel ("Saskatchewan," interglacial?); pebbles exclusively from the Rocky Mountains, well rounded, ranging from less than an inch to 1½ feet in diameter	10–15
Cretaceous rock.	

This is the most southerly point at which the writer observed the quartzite gravel underlying drift of the St. Mary Glacier that is in turn overlain by drift of the Keewatin ice sheet.

EROSION AND REFILLING IN MILK-MISSOURI VALLEY

In this connection it is well to consider the depth and character of the filling in the old valley of the Missouri River, now occupied by the Milk River below Havre and followed through most of its extent below the mouth of the Milk River in Montana by the present Missouri River.

Stebinger[9] quotes the log of a well drilled by the Quartermaster's Department, United States Army, at Fort Assinniboine, Mont., between June, 1892, and November, 1893, which shows 65 feet of clay, gravel, and sand overlying the Bearpaw shale. This is probably near the southeast side of the buried valley.

Calhoun[10] states that south of Havre there is a drift filling 140 feet thick in the old Missouri Valley.

The west pumping station of the waterworks at Havre is in the mouth of a small coulee below the hospital, in the southwestern part of the town, in the SW. ¼ sec. 8, T. 32 N., R. 16 E., at about 2,530 feet above sea level. In August, 1920, W. R. Crafts, in charge of the pumping stations, informed the writer that at this station there were 10 wells dug to an average depth of 110 feet in gravel, and at the east station at Fifth Avenue and Third Street points had been driven to depths of 70 to 90 feet. The west station is 80 to 100 feet lower than the upland to the southwest, which forms the bottom of a sag more than 2 miles in width beneath which lies buried the old Missouri River Valley. It is probable, therefore, that there is at least 200 feet of filling in this old valley, whose bottom is less than 2,420 feet above sea level, or 50 to 75 feet lower than the Milk River.

In 1921 the writer made a hasty examination of an old gravel pit at a coulee cutting the south bluff of the Milk River Valley west of Toledo, in the NE. ¼ sec. 5, T. 32 N., R. 17 E. The sides of the pit were badly obscured and partly overgrown. There is here a thick bed of quartzite gravel in which no pebbles identifiable as glacial drift were found by the writer. At one point overlying this stratified gravel was 5 to 10 feet of gravel which is clearly of glacial origin, inasmuch

[8] Dawson, G. M., and McConnell, R. G., Glacial deposits of southwestern Alberta: Geol. Soc. America Bull., vol. 7, p. 43, 1895.

[9] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, p. 72, 1917.

[10] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof Paper 50, p. 38, 1906.

as it contains granitic pebbles such as occur in the glacial till. At another point the lower nonglacial gravel was overlain by a bed of dense gray jointed pebbly glacial till which was rusted along joint faces and presented the appearance of having been disturbed by being overridden by a glacier. Overlying this was dull buff till of the Wisconsin drift sheet, and at another place the lower till was overlain by 20 feet of glacial gravel. The exposure is poor, and the examination was too hasty to be conclusive. The conditions as seen suggest the presence of glacial gravel, of two deposits of glacial till, the older one possibly of Iowan or Illinoian age, and of an underlying bed of nonglacial gravel. This exposure is near the east side of the old buried valley of the Missouri River where it is cut across by the present inner valley of the Milk River. The latter valley is less than half a mile in width in this vicinity, though about 8 miles farther east it is nearly 3 miles wide. Other gravel pits near Chinook have not been examined.

In 1890 a well was drilled at Chinook in an attempt to develop artesian flow. According to the log quoted by Stebinger,[11] this well penetrated loam and sand 112 feet and "stone boulders" 12 feet over stiff clay (shale) and sandstone. It is not known that the "stone boulders" are glacial drift.

The record of the deep well at Chinook, where 124 feet of filling was penetrated, indicates that there is probably at least 125 feet of filling in the Milk River Valley at Harlem—that is, the bottom of the inner valley beneath this filling is about 400 feet lower than No. 2 bench north of Harlem, or 2,240 feet above sea level.

In 1917 Collier examined excavations at Wolf Point where gravel was being dug from the bank north of the Great Northern Railway shops then being built. These were reexamined by the present writer in 1920, together with smaller pits near the cemetery northwest of the town. Wolf Point is about 25 feet above the Missouri River, and the bench in whose edge are the gravel pits is about 20 feet higher. Collier[12] gives the following description of the deposits, which were better exposed in 1917 than in 1920:

Section exposed in gravel pit at Wolf Point

	Feet
Soil with a few scattered granite boulders on the surface	1
Glacial till, containing granite cobbles	5
Gravel, chiefly quartzite but containing fragments of sandstone, porphyry, and near the bottom shale	13
	19
Shale, Bearpaw.	

The gravel is interstratified with lenses of sand, and the bedding planes are nearly horizontal. The gravel consists for the most part of well-rounded pebbles of quartzite, probably derived from the Flaxville gravel, but it contains some pebbles of porphyry and fragments of sandstone and fossiliferous Bearpaw shale near the bottom. A thorough search failed to reveal any glacial material such as granite pebbles.

There are some highly fossiliferous concretionary masses from the Cretaceous shale. Many pebbles and boulders of limestone and granite were seen by the present writer in the till and also on the bottom of the excavations, but none were found in place in the undisturbed gravel. Apparently the granite and limestone pebbles came from the overlying glacial till. It is probable, therefore, that the gravel was deposited in the valley before the advent of the glacier. The same relation was found in the pits near the cemetery and in those examined north of Malta (p. 44).

Collier also writes:[13]

Another gravel pit 2 miles west of Brockton shows finely laminated sand. The bedding at the west end of the pit lies nearly horizontal, whereas that at the east end dips east about 70°. The surface has been eroded irregularly and is covered with glacial till to a maximum depth of about 15 feet. The bottom of this pit is about 40 feet above the present river level.

The following log of the village well at Wolf Point shows the depth and character of the filling under the flat on which the village stands, at a point a short distance south of the railway, which is at the north side of the inner valley about 25 feet above the river.

Log of well at Wolf Point, Mont.[a]

	Thickness (feet)	Depth (feet)
Clay	35	35
Quicksand	6	41
Gravel	15	56
Blue clay	2	58
Quicksand	17	75
Blue clay	5	80
Quicksand	11	91
Gravel	9	100

[a] Record from Peter Lenz, superintendent of waterworks; well drilled in 1897.

From these too meager observations it appears that before the invasion of Montana by the Keewatin ice sheet the Missouri River had cut down well below the present level of the Milk River at least as far west as Havre, and that after being cut the gorge was partly refilled with clay, sand, and gravel to a level above that of the present flood plain. Perhaps this cutting was due to rapid deepening of the Missouri gorge through the Dakotas after the Kansan stage of glaciation. It is not clear that it was due to regional uplift, inasmuch as there are no data in hand to show that deepening and refilling occurred more than a short distance up the Yellowstone Valley.

During the advance of the Keewatin ice sheet at the Iowan or Illinoian (?) stage of glaciation an im-

[11] Stebinger, Eugene, op. cit., p. 81, quoted from Nettleton, E. S., Final report on artesian and underflow investigation to the Secretary of Agriculture: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, pp. 72–73, 1892.

[12] Collier, A. J., Geology of northeastern Montana: U. S. Geol. Survey Prof. Paper 120, p. 36, 1919.

[13] Idem, p. 36.

mense amount of water must have been diverted southeastward from Canada into the Missouri River. This would assist the cutting until the ice front reached and blocked the gorge in North Dakota and Montana. After that occurred the drainage was forced into temporary channels about the edge of the ice (p. 88) until the ice front again receded.

ILLINOIAN OR IOWAN (?) STAGE OF GLACIATION

There seems to be no clear evidence that the Keewatin ice sheet invaded Montana at either the Nebraskan or the Kansan stage of glaciation. Neither is it certainly known that there was extensive development of the Keewatin glacier at the Illinoian stage, when the Labradorean ice sheet extended southwestward over most of Illinois and encroached on southeastern Iowa. After the Sangamon stage of deglaciation, however, there came on a new development and extension of the great Keewatin ice sheet centering in the Hudson Bay region. The ice spread southward across Minnesota into northern Iowa and left a deposit of drift of moderate thickness, which has been regarded as of pre-Wisconsin age but not so old as the Illinoian drift of the Labradorean ice sheet.[14] There are some good reasons, as it seems to the writer, for thinking that the drift found in the Dakotas and in Montana, outside what is regarded as the limit of the Wisconsin drift, is not older than the Iowan drift. It is possible, however, that it is really of Illinoian age. This may include the outer drift mapped by Calhoun along and south of the Missouri River, and, if so and if it is of Iowan age, it indicates that the Iowan ice sheet reached its maximum southwesterly extent in the region of Great Falls, Mont.

There seems to be no reason for thinking that general altitudes above sea level in this region were very different, after the development of the third set of terraces, from what they are now. The big uplift evidently had preceded the formation of that bench or set of terraces. Perhaps an uplift amounting to a few hundred feet in the mountains accompanied the trenching of No. 3 bench near the mountains, and with this is perhaps to be correlated some of the filling of the inner valleys farther east, where the gradient was lower and there may perhaps have been some later uplift. This is discussed above (p. 104). If the advancing ice sheet first reached the Missouri River in the Dakotas, the waters in the valley above must have been ponded and forced to find a higher outlet somewhat farther west. This ponding of the waters would help to furnish the conditions required for deposition of the filling of clay, sand, and gravel described above. As the ice occupied the valley farther and farther west deposits of till and boulders were added to the filling, and in places, as at Wolf Point, Brockton, Malta, and Toledo (p. 67), glacial till overlies the nonglacial stream deposits.

PRE-WISCONSIN DRIFT OF THE MOUNTAIN GLACIERS AT LOW LEVELS

It is of some importance to know whether there is any evidence of an advance of the mountain glaciers after the time of development of the lower level of the second set of terraces and yet prior to the well-marked extension of the Wisconsin stage—that is, of an extension of the mountain glaciers at relatively low levels corresponding to the evidence that a pre-Wisconsin ice sheet invaded this region from the Hudson Bay region, after the plains had been degraded and the streams had cut down to or below their present levels. Good evidence of such a glacial advance down onto the Circle terrace at the Bull Lake stage of glaciation (of Blackwelder[15]) is found in the Wind River Mountains of Wyoming. There is some such evidence in the Glacier Park region, but it is very meager and is not regarded as conclusive. The evidence consists of the following section:

Section of glacial and interglacial deposits at Glacier Park station

	Ft.	in.
Wisconsin glacial drift and outwash: Stratified gray gravelly drift, more clayey at top	15	
Interglacial deposits (?):		
Sand and yellow laminated clay		5
Black soil with rootlets		5
Black sandy clay	3	
Iowan or Illinoian (?) glacial drift: Rusty pebbly drift, partly cemented to conglomerate; stones becoming coarser downward to boulders 1 to 4 feet in diameter; masses of black shale included	15	
Cretaceous black shale; upper layers broken up and overthrust eastward in small folds as if by ice push	5	

The exposure is in a ravine near the railway water tank. The deposits above the black shale suggest pre-Wisconsin glacial drift overlain by an interglacial soil, and this in turn overlain by Wisconsin glacial drift or outwash. As this older drift is exposed at about 4,750 feet above sea level, or about 1,300 feet lower than the base of the high-level pre-Wisconsin till on the ridge north of lower Two Medicine Lake, 7 miles northwest of Glacier Park station, and as it is composed entirely of fragments from the pre-Cambrian and from underlying Cretaceous rocks of the mountains to the west, it suggests a rather late stage of mountain glaciation.

This section was in less satisfactory condition when reexamined in August, 1920, and July, 1921. There

[14] Alden, W. C., and Leighton, M. M., The Iowan drift, a review of the evidences of the Iowan stages of glaciation: Iowa Geol. Survey, vol. 26, pp. 49–212, 1917.

[15] Blackwelder, Eliot, Post-Cretaceous history of the mountains of central western Wyoming: Jour. Geology, vol. 23, p. 310, 1915.

was, however, a suggestion of two stages of glaciation, though all trace of buried soil had disappeared. At the bottom was exposed about 15 feet of rusty, very stony till overlain by 5 feet of gravel. Above this was about 4 feet of gray till, overlain in turn by 5 feet of gravel.

About 1½ miles farther down Midvale Creek, in sec. 29, T. 31 N., R. 12 W., the following section was seen in 1911:

Section of glacial and interglacial (?) deposits southeast of Glacier Park station

	Feet
Wisconsin glacial drift: Loamy soil, gravel, and boulders	5–10
Interglacial (?) lake deposit: Fine laminated buff silt (loesslike)	15–25
Iowan or Illinoian (?) glacial drift: Gravelly drift	(?)
Cretaceous deposits.	

About 25 miles farther east down the Two Medicine Valley, 3 miles east of Family, in sec. 31, T. 32 N., R. 8 W., Stebinger observed the following section in 1912 as shown by his field notes:

Section of glacial and interglacial (?) deposits on Two Medicine Creek in 1912

	Feet
Recent:	
Gray sandy loam	2
Red soil with a few small pebbles	1½
Wisconsin drift of Two Medicine Glacier: Clayey till containing striated pebbles of mountain rocks	10
Interglacial deposits: "Old soil," a bluish-black clay	2
Iowan or Illinoian (?) drift of Two Medicine Glacier:	
Blue-gray pebbly clay and unassorted pebbles and boulders of mountain rocks, partly striated	2
Yellow to buff pebbly clay and unassorted pebbles and boulders of mountain rocks, partly striated	3
Cretaceous: Bearpaw shale, weathered at top	100

This section is at the apex of the sharp bend in the stream, so that there is active cutting and slumping, and the upper part of the section was almost inaccessible for close inspection in September, 1920, when it was visited by the present writer. The section is about 1½ miles south of the point where the irrigation canal leaves the Two Medicine Valley and enters the lower of the two sags where Flat Coulee was beheaded, as described above. It is clear that all the drift exposed at this place was deposited after Two Medicine Creek had abandoned that coulee and had cut down within 100 feet of its present level. The following is the section as exposed in 1920:

Section of glacial and interglacial deposits on Two Medicine Creek in 1920

	Feet
4. Recent: Gray loamy soil	1
3. Wisconsin drift of Two Medicine Glacier:	
Reddish-brown pebbly weathered zone	½
Clayey till, grayish, containing striated pebbles or mountain rocks only	5–10
2. Interglacial (?) deposits: Dark rusty-gray clay, containing some decayed pebbles	2
1. Iowan or Illinoian (?) drift of Two Medicine Glacier:	
Dull buff to gray till, containing pebbles of mountain rocks only	5
Cretaceous: Bearpaw shale, weathered brownish at top	100

The section does not demonstrate pre-Wisconsin glaciation at this place, though the oxidation of No. 2 and the top of No. 1 and the presence of the decayed pebbles seem to indicate an interval of exposure to weathering before the gray till (No. 3) was deposited. In one place the clay (No. 2) appears to have been shoved up eastward and a thin stringer is drawn out from this into the till above, as if due to drag of the later ice sheet as it advanced eastward down the valley. The weathered and eroded top of the dark shale below the lower till is about 60 feet below the level of the canal in the sag to the north.

The presence of hard cemented glacial gravel at several places on Badger and Little Badger Creeks also suggests pre-Wisconsin glaciation.

One section on the St. Mary River about 2 miles below the mouth of Kennedy Creek, in the SW. ¼ sec. 25, T. 37 N., R. 14 W., examined by the writer in 1911, and two sections close together a mile or less below this point, about a mile above the Bureau of Reclamation camp at Fletcher, which were examined by Stebinger and the writer in 1912, suggest two extensions of the St. Mary Glacier after the valley had been cut nearly to its present depth. These sections are as follows:

Sections of glacial and lacustrine deposits on St. Mary River north of Babb

No. 1

	Feet
Wisconsin drift of St. Mary Glacier: Glacial till containing mountain rocks and masses of clay from underlying beds	3–10
Lacustrine deposits: Fine stratified sand and clay containing few or no pebbles except near the top, where small pebbles of pre-Cambrian granite from Canada were found (probably berg-transported)	35
Iowan or Illinoian (?) glacial outwash: Gravel; pebbles of mountain rocks only, some striated	3
Cretaceous: Sandstone, partly disintegrated at top	20

No. 2

Recent: Wind-blown sand	0–3
Wisconsin drift of St. Mary Glacier: Glacial drift containing pebbles of mountain rocks	6–10
Lacustrine deposits: Fine stratified sand	4–8
Iowan or Illinoian (?) drift of St. Mary Glacier:	
Sandy till containing striated pebbles of mountain rocks	3–12
Interstratified fine sand and silt laminated with some fine gravel	6
Cretaceous:	
Fine rippled sand or decomposed sandstone	30
Sandstone	30

No. 3

	Feet
Recent: Stratified clay and sand	18
Wisconsin drift of St. Mary Glacier: Glacial till containing many pebbles of mountain rocks	6
Lacustrine deposits: Stratified sand and clay	20
Iowan or Illinoian (?) drift of St. Mary Glacier: Glacial till containing many pebbles of mountain rocks	5
Cretaceous: Clay and sandstone	30

Although these three sections do not afford good evidence of an interglacial stage, the presence of the lacustrine deposits between the two deposits of glacial drift shows at least a short interim between the advances of the St. Mary Glacier. The presence of the small pebbles of pre-Cambrian granite from Canada at the top of the lake beds at one place, on the other hand, suggests that the ponding of water in the valley was due to the Keewatin ice sheet.

It is not yet certain that the relations of wind-blown deposits in the region of the mountain front are particularly significant. There are a few exposures where a deposit of loess occurs between the pre-Wisconsin and Wisconsin continental tills. If this loess corresponds in age to the main deposit of loess along the lower Missouri and Mississippi Rivers in Iowa, which overlaps Iowan till, it may be that the low-level mountain till which it overlies near the mountain front is also Iowan or older.

In places where till or outwash gravel of the mountain glaciers is overlapped by till of the continental ice sheet a deposit of loess and in some places a black soil intervenes. In these places it may be that the overlapped mountain till or outwash is either Iowan or Illinoian rather than Wisconsin, as Calhoun[16] supposed. It may also be that some, at least, of the lacustrine deposits in the sections cited by Calhoun are the results of ponding of the streams by the Iowan or Illinoian ice of the Keewatin glacier. If this is the case, the underlying mountain till and outwash gravel are probably also either Iowan or Illinoian.

Calhoun[17] cites one section on the Belly River at the terminal moraine of the Keewatin ice sheet, showing in order, beginning at the bottom:

A, Till formed by Belly River Glacier containing many boulders, all of which are smoothed and striated to an unusual degree, 75 feet; B, soil, of which only a small exposure was seen, which contained no fossils; C, till formed by the Keewatin ice sheet, 80 feet.

He did not, however, regard the soil (B) as indicating any considerable lapse of time between the deposition of the mountain drift (A) and the overlying drift of the Keewatin ice sheet (C). No such intervening bed as the soil (B) was observed by the present writer in any of the exposures where mountain drift was seen overlain by drift from the Keewatin ice. The sections cited above are regarded as suggestive of what more detailed studies may reveal rather than as very important or at all conclusive in themselves.

PRE-WISCONSIN DRIFT OF THE KEEWATIN GLACIER UNDERLYING LATER DRIFT

At several places west of the latitude of the Cypress Hills and Bearpaw Mountains exposures of pre-Wisconsin drift of the Keewatin ice sheet have been seen by Stebinger and the writer, and the fact that none of these are much more than 100 feet above the present streams is regarded as evidence that the glacier making the deposits did not invade this region until later than the time of development of the lower level of the second set of terraces—that is, long after the time of deposition of the high-level drift of the mountain glaciers found on No. 1 bench and the upper No. 2 bench in the Glacier National Park region, and not very long before the Wisconsin stage of glaciation. On this basis it might be inferred that the deposits are those of the Iowan stage of glaciation. The fact that it has not yet been demonstrated that there was at the Illinoian stage an advance of a glacier from the west side of Hudson Bay, corresponding to the Labradorean glacier of that stage, lends weight to a tentative correlation of the deposits with the Iowan drift, as represented in northeastern Iowa.

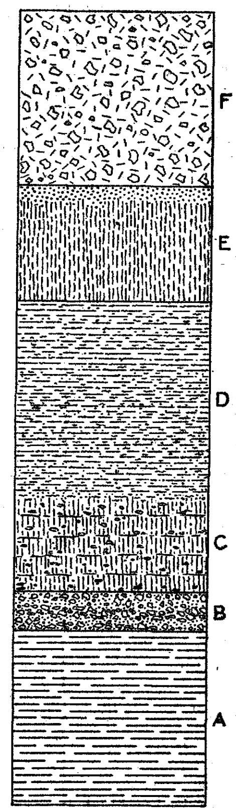


FIGURE 3.—Section on St. Mary River north of Sloan's ranch, Mont. A, Shale; B, northeastern drift, 2 feet, containing many decomposed boulders; C, typical loess, 5 feet, containing concretions, hard shells and bones of small animals; D, soil, 10 feet of black clayey loam, consisting of the weathered upper part of the lower loess bed; E, loess, 6 feet, sandy at the top; F, northeastern till, containing crystalline boulders. (From F. H. H. Calhoun.)

Calhoun[18] illustrates a section observed by him on the St. Mary River north of Sloan's ranch, a few miles north of the international boundary, by a figure, reproduced here as Figure 3.

The present writer examined numerous exposures on the St. Mary River in 1912 and 1920, both above and below Sloan's ranch, but this section, if still preserved, is evidently one of those which were not examined. This section is particularly interesting because, if the lower bed of northeastern drift (B) is in reality unmodified pre-Wisconsin glacial till deposited by the Keewatin ice sheet, it means that the St. Mary Valley had at the

[16] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, pp. 46–49, 1906.
[17] Idem, p. 49, fig. 31.
[18] Idem, fig. 30.

time of that glacial extension been cut down approximately to its present depth, more than 1,000 feet below the level of the pre-Wisconsin mountain drift on the Hudson Bay divide, 8 or 10 miles to the south and more than 1,600 feet lower than the drift capping Kennedy Ridge, a few miles farther southwest.

In response to a letter of inquiry concerning this bed (B) of northwestern drift, Calhoun[19] wrote in part as follows:

Along this river in the vicinity of Sloan's ranch there had been a great deal of slumping, and, with the time and help that I had at my command, I could not take the trouble to make any excavations. I was satisfied in my own mind that the lower bed (B) was really part of the older drift sheet, but, although I looked for many days, I found nothing else in any other river valley to substantiate this. The age of the boulders in the two sheets, as shown by the amount of weathering to which they had been subjected, was very different, and if I remember rightly, as far as I could make out from the badly weathered specimens, the rock material was also different. I left the section very much pleased with what I thought was evidence that could not be disputed as to the existence of two different ice sheets from the northeast, but after many weeks of search I came to the conclusion that it would not do to claim the existence of another sheet upon the evidence of one section.

The layer B was a layer of boulders—some of them igneous and every one badly decomposed. In this layer there was not one sound rock of igneous origin, although there were quartzite gravels in the formation which were not decomposed. These decomposed igneous rocks occurred in considerable numbers. I am not sure whether the deposit was till or material let down by erosion. If it was till, it was very stony till. I found no other deposit in the area which contained badly decomposed igneous rock of undoubtedly northeastern origin.

It is not probable or, as it seems, possible, on account of the topographic relations, that the Keewatin ice was depositing the bed of drift (B) at so low a level in the St. Mary Valley, in the vicinity of Sloan's ranch, at approximately the same time that the mountain glaciers were depositing the drift on the high-level tracts. This is a reason for regarding this pre-Wisconsin drift in the valley as perhaps not older than Iowan.

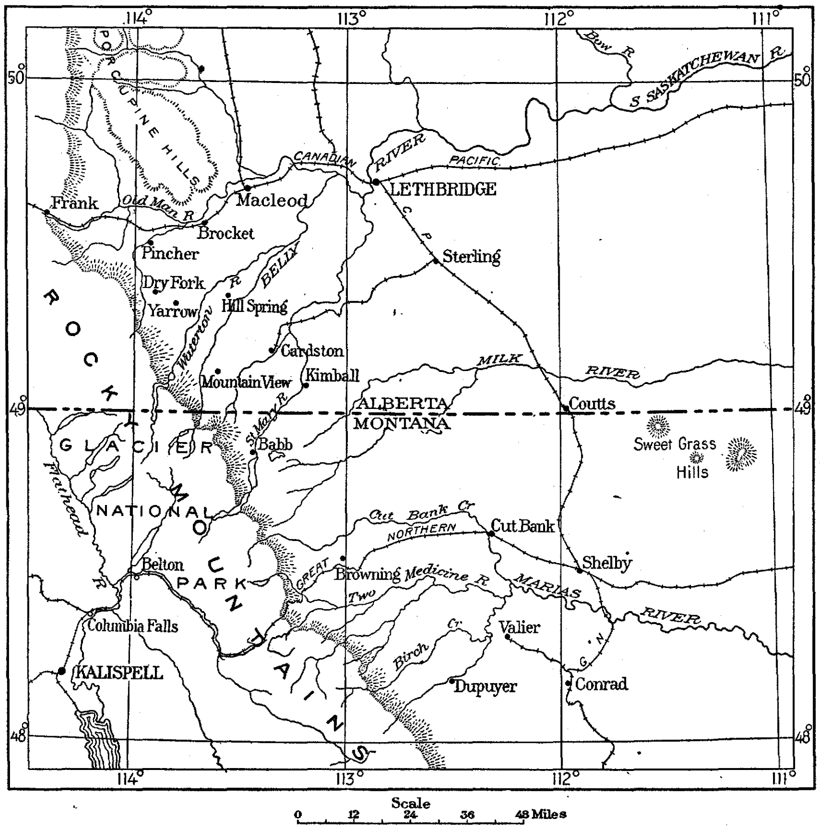


FIGURE 4.—Map of portions of southern Alberta and northern Montana

Farther north, on the Belly River near Lethbridge and on the Old Man River as far west as Brocket (fig. 4), there are considerable deposits of unmodified glacial till, a part of which evidently is and a part of which may be of pre-Wisconsin age, exposed in the bluffs and unquestionably in place, not far above the present streams.

In the course of a reconnaissance trip in southern Alberta in 1912 the writer spent a day at Lethbridge and made an examination of the series of drift deposits described by Dawson.[20] In the time spent, however, there was opportunity for study of only a small part of the fine exposures in this vicinity. For some distance both north and south of the railway bridge at this place the drift deposits are well exposed in the bluffs forming the sides of the valleys. The Belly River Valley is here about 300 feet in depth, a steep-sided trench cut in the undulating plain. From the railway station down into the valley south of the railway bridge to the vicinity of the municipal coal mine, filter beds, and electric-power house, the following series of deposits was observed in the east bluff:

Section of Pleistocene deposits on Belly River at Lethbridge, Alberta

	Feet
4. Wisconsin stage: Buff loose-textured to moderately compact clayey till of Keewatin ice sheet containing plentiful pebbles of pre-Cambrian rocks from the northeast and Paleozoic (?) limestone pebbles, beneath upper grassed slope	150±
3. Interglacial: Fine gray compact cemented sand or silt with, in places, some intercalated thin layers of brown to black lignitic material; locally contorted in part; clay-iron nodules in places at top of bare shoulders of the bluff	10±

[19] Personal communications, Nov. 25 and 30, 1912.

[20] Dawson, G. M., and McConnell, R. G., Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains: Geol. Soc. America Bull., vol. 7, pp. 39–41, 1895.

	Feet
2. Iowan or Illinoian stage (?): Dense, compact dark-gray till of Keewatin ice sheet; pebbles mostly from the Rocky Mountains; pebbles of pre-Cambrian crystalline rocks from the northeast plentiful but less abundant than in upper till; forms bold salient of the bluff	40–50
1. Interglacial: Stratified gravel ("Saskatchewan") composed mostly of 4 to 6 inch well-rounded pebbles of quartzite from the Rocky Mountains	10–12
Cretaceous shale and coal.	

The bluff on the opposite side of the river at the bend north of the wagon bridge exposed the following section. (See fig. 5.)

Section of Pleistocene deposits on Belly River near Lethbridge, Alberta

	Feet
4. Wisconsin stage: Loose buff till of Keewatin ice sheet, with pebbles of pre-Cambrian crystalline rocks from the northeast and pebbles from Rocky Mountains	3–13
3. Interglacial:	
Laminated papery silt	1–3
Buff wind-bedded loess, alternating with beds of fine stratified sand	0–50
2. Iowan or Illinoian stage (?): Compact jointed till of Keewatin ice sheet, with pebbles of pre-Cambrian crystalline rocks from the northeast and pebbles from Rocky Mountains. Upper 15 feet oxidized buff in places, dark gray below	25–30
1. Interglacial: Quartzite gravel ("Saskatchewan"), with some interbedded sand	10–15
Cretaceous shale	100

The gravel (1) in the two sections, which represents the "Saskatchewan" gravel of Dawson and McConnell, is made up exclusively, where examined, of water-worn pebbles from formations exposed in the mountains 60 miles to the west and southwest, mostly of pink and white quartzite, with smaller percentages of maroon and greenish argillite, diorite, amygdaloidal trap rock, gray limestone, and conglomerate containing black chert pebbles. At one point two or three fragments of granite were found among the loose pebbles in the excavation, but it was thought they might have rolled down from the drift higher in the slope, which was deposited by the Keewatin ice. No such fragments were found embedded in the stratified gravel. The top of the gravel is marked by a sharp horizontal line, and at only one point was there any evidence of disturbance of the bedding, such as might be expected to result from its being overridden by the continental ice sheet. Perhaps the gravel was cemented by ice to a solid mass when such overriding took place.

By far the larger percentage of the pebbles in the dense, compact lower till (2) came from the Rocky Mountains, probably derived by the glacier from deposits of gravel in the valleys such as those composing the underlying bed. Intermingled with these are pebbles of granite and other crystalline rocks from the pre-Cambrian formations west of Hudson Bay, showing that the till was deposited by the Keewatin ice sheet. The surface of the lower till is uneven, especially in the second exposure described, and the oxidation of the upper part of this till is evidence of its exposure to weathering prior to the deposition of the upper till.

The stratified beds (3) indicate deposition during a stage of deglaciation. At the exposure north of the bridge there is nearly 50 feet of interbedded fine sand and loesslike silt resembling an eolian deposit. Overlying this is 1 to 3 feet of fine laminated papery silt. The relations indicate that this deposition was followed by a period of erosion, for the deposit thins abruptly toward the east side of the exposure until it pinches out entirely between the lower till (2) and the upper till (4). The upper till (4) mantles the slope and extends thence up to the upland as if it lay on the side of an interglacial valley. The extent of the interglacial deposit (3) northward down the valley was not determined. There seemed to be considerable of the loesslike material on the east side north of the railway bridge, where such material exposed in the sides of a ravine was being used in making brick. South of the railway bed 3 consists of partly cemented, laminated grayish fine sand or silt. A small opening in the grassy slope at one point in the side of a ravine back of the power house exposed as part of these deposits the following beds:

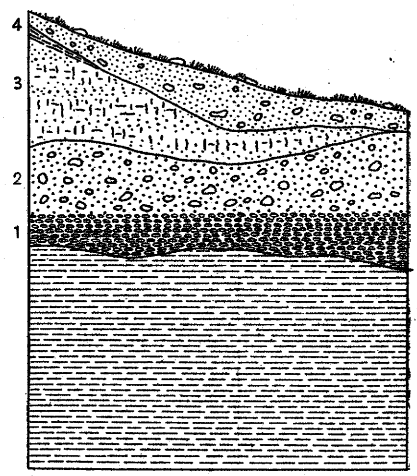


FIGURE 5.—Section on Belly River near Lethbridge, Alberta. 1, Quartzite gravel ("Saskatchewan," interglacial), 10 to 15 feet, overlying Cretaceous shale; 2, pre-Wisconsin till of Keewatin ice sheet (Iowan or Illinoian?), 25 by 30 feet; 3, loess and wind-blown sand, 0 to 50 feet, overlain by laminated silt, 1 to 3 feet (interglacial); 4, Wisconsin till of Keewatin ice sheet, 3 to 13 feet

Partial section of interglacial beds at Lethbridge, Alberta

	Inches
Sand, top not exposed.	
Soft, brownish vegetal material	0–½
Sand	4
Brownish vegetal material in thin layers	4
Sand	0–3
Black lignitic material, partly glistening coal	¼–1
Sand, bottom not exposed.	

The beds at this point were much contorted, either as the result of slumping or possibly from having been overridden by the later ice sheet, so that it could not be determined that the vegetal material had actually grown where deposited. At one point, however, fine rootlike fibers were noted extending downward from one of the vegetal layers into the sand below. The vegetal material probably corresponds to the peaty or lignitic material observed by Dawson [21] at this horizon several miles farther down the valley and represents one of the several phases of interglacial deposition in this region.

The upper till (4) is of looser texture, and a higher percentage of the included pebbles are of pre-Cambrian crystalline rocks from the northeast than in the lower till (2), although even here a considerable proportion of them are from the mountains.

About 200 yards below the confluence of Willow Creek and the Old Man River, a few miles northeast of Macleod, in T. 9 N., R. 25 W., the following section was observed:

Section of Pleistocene deposits on Old Man River near Macleod, Alberta

	Feet
4. Gray sandy unstratified loam	0–3
3. Wisconsin stage: Buff to gray loose till containing pebbles from the Rocky Mountains and a good percentage of the pebbles from the pre-Cambrian crystalline rocks from the northeast	15–20
2. Interglacial: Dark fine laminated silt, a few inches.	
1. Iowan or Illinoian stage (?): Very dense, hard gray till containing pebbles from the Rocky Mountains and a somewhat smaller percentage of crystalline pebbles than in 3; overlies the eroded surface of the Willow Creek formation (Cretaceous or Tertiary) and fills two coulees eroded therein	20–30

It is thought that deposits 1 and 2 in this section may correspond respectively to deposits 2 and 3 in the sections at Lethbridge.

In none of the sections examined in this locality was the "Saskatchewan gravel" present, and in none other than those given above was any evidence of more than one till observed. At some of the localities, however, the bottom of the drift filling the preglacial valley has not yet been reached by the stream.

Farther west up the valley of the Old Man River a section was observed at the wagon bridge near Brocket, 16 miles southwest of Macleod, in the Piegan Indian Reservation, exposing the following beds:

Section of Pleistocene deposits near Brocket, Alberta

	Feet
4. Recent coarse gravel underlying a river terrace and lying on the eroded surface of the till	15
3. Wisconsin stage: Dense dark-gray till; pebbles mostly from the Rocky Mountains, with a small percentage of pebbles of pre-Cambrian crystalline rocks from the northeast	0–20
2. Interglacial: Dark laminated silt	1–3
1. Iowan or Illinoian stage (?): Dense gray till, not very stony; pebbles mostly from Rocky Mountains, with a very small percentage of pebbles of pre-Cambrian crystalline rocks from the northeast	30

[21] Dawson, G. M., Canada Geol. Survey Rept. Progress for 1882–1884, p. 144c, 1885.

Here again deposits 1 and 2 may perhaps represent beds 2 and 3, respectively, in the Lethbridge exposure.

This is the most westerly point at which any evidence of more than one sheet of till deposited by the continental glacier was observed. At the nearest point the mountain front is distant about 20 miles to the southwest. At the exposure near Brocket the river has not yet cut down to the bottom of the drift filling in the preglacial valley. From this relation it appears that at least one of the main streams had cut below its present level before the first invasion of the region by the Keewatin ice sheet of which there is evidence.

In the vicinity of the confluence of the Waterton and Belly Rivers and southwestward to points within a few miles of the village of Hill Spring, Alberta, in T. 4 N., R. 27 W., numerous places were observed where the bottom of the drift filling has not yet been reached by the streams. In these places, however, no conclusive evidence that the lowest till exposed is older than the Wisconsin stage was noted. It can not be asserted, therefore, that the valleys of these streams were deeper than now this far south at the time the lower drift was being deposited in the vicinity of Lethbridge. The general relations, however, suggest that there were pre-Iowan or pre-Illinoian channels about as deep as the present ones, as indicated by the "Saskatchewan gravel" described above.

Evidence showing the presence of pre-Wisconsin till beneath the later drift south of the international boundary is very meager. About 15 miles east of the Sweetgrass Hills, in a small coulee tributary to Sage Creek from the north, in T. 36 N., R. 8 E., the following section was observed in 1913 by Stebinger [22] in good exposures extending several hundred feet along the nearly vertical banks of the coulee:

Section of Pleistocene deposits near Sage Creek, T. 36 N., R. 8 E., Mont.

	Feet
Wisconsin stage: Stony, compact till of Keewatin ice sheet containing abundant pebbles of pre-Cambrian crystalline rocks and Paleozoic (?) limestone from the northeast. This till is as fresh and unweathered as that usually found in the drift of Wisconsin age	5
Iowan or Illinoian stage (?): Stony, compact, but much weathered till of Keewatin ice sheet, containing many pre-Cambrian crystalline pebbles from the northeast but very few if any limestone pebbles	6
Cretaceous clay and sandstone of Judith River formation.	

The recognition of two separate drift sheets in this section rests entirely on the difference in amount of weathering, their general composition and appearance being almost identical except in this particular. In the older till the crystalline pebbles are so much de-

[22] 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. 571–572, 1913.

cayed and friable that they fall to pieces with a light blow from the hammer; in the upper till they are firm and fresh and practically unweathered. The limestone pebbles, which are fairly abundant in the upper till, are almost entirely leached out of the lower, which is partly indurated in places and deeply iron-stained. The difference in the appearance of these two bands of till is so marked that they can easily be distinguished at a distance of a quarter to half a mile. From the amount of weathering present it seems evident that the time interval between the lower and upper of these two tills is much greater than that between the upper (Wisconsin) till and the present.

On the whole, it seems reasonable to infer that the lower till here found corresponds to the lower till found on the Belly River at Lethbridge, Alberta, and also probably to the continental drift found south of the margin of the Wisconsin drift in Montana and western North Dakota.

Evidence of pre-Wisconsin glaciation afforded by an old gravel pit on the south side of the Milk River west of Toledo, in the NE. ¼ sec. 5, T. 32 N., R. 17 E., is found in the section described above (p. 67). At this place traces were seen in 1921 of a bed of dense gray jointed pebbly glacial till, which was rusted along the joint faces and presented the appearance of having been disturbed as by an overriding glacier. It is underlain by a bed of nonglacial gravel and overlain by glacial gravel and a later bed of glacial till.

An exposure in a bluff on White Bear Creek in the Fort Belknap Indian Reservation, southeast of Harlem, in T. 30 N., R. 24 E., examined in 1921 showed 4 feet of gravel separating two beds of glacial till. Nothing was noted, however, which indicated that the lower till was appreciably older than the upper one.

PRE-WISCONSIN (ILLINOIAN OR IOWAN?) DRIFT BORDERING THE MISSOURI RIVER IN NORTH DAKOTA

That a pre-Wisconsin ice sheet extended some distance south and west across the present course of the Missouri River in North Dakota is shown by the presence there not only of scattered glacial pebbles and boulders but also by the existence of a considerable deposit of glacial till. Knowledge of the distribution of this glacial material is the result of the work of numerous geologists—T. C. Chamberlin,[23] R. D. Salisbury, A. G. Leonard, F. A. Wilder, J. E. Todd, C. M. Bauer, and F. A. Herald. The southwestern limit of glacial material is shown in Figure 6 as drawn by Leonard.[24]

In the course of several traverses between the eastward trending parts of the courses of the Missouri and Little Missouri Rivers in McKenzie County in 1916 and 1921 the present writer also observed scattered boulders and numerous exposures of glacial till. One of these was on Charbonneau Creek south of Cartwright, where there is 10 to 20 feet of dull brownish-buff pebbly clay till overlying stratified clay or shale. Shallow road cuts on the gently rolling and little dissected upland north of the creek show the presence of a sheet of till. In this drift and on the surface are plentiful pebbles of red and yellow (Belt?) quartzite, agate, and chert, with pebbles and boulders of limestone and crystalline rocks (mostly granite) from Canada. Between Arnegard and Watford City a succession of cuts along the Great Northern Railway exposed thicknesses of 1 to 25 feet of glacial till overlying friable cross-bedded Fort Union sandstone. Wilder[25] reports 25 feet of glacial drift at Glass Bluff, 4 miles southeast of Buford, on the south side of the Missouri River.

Leonard[26] gives the following description of several excellent exposures of drift in McKenzie County:

> Near the western boundary of North Dakota the pre-Wisconsin ice sheet reached 35 to 40 miles south of the Missouri River and thus covered the greater part of McKenzie County, which lies between the Yellowstone, Missouri, and Little Missouri Rivers. The older drift left by this ice sheet is well shown in many places in this region, and the glacier also caused important drainage changes. The best exposures are found on Sand Creek, a short tributary of the Missouri River several miles east of Tobacco Garden Creek, on Tobacco Garden Creek, and on Clear Creek, a tributary of the latter.
>
> Near the mouth of Tobacco Garden Creek appears 58 feet of till in a cut bank. It is yellowish gray or drab in color, contains many small boulders, and rests on Fort Union beds. Not far from here is seen 18 feet of boulder clay overlying 15 feet of well-stratified sand and gravel.
>
> The valley of Clear Creek was partly filled with drift, and there are many good outcrops of boulder clay in the frequent cut banks along the streams, where from 30 to 40 feet and over of till is exposed. The greatest thickness found along this creek was in sec. 36, T. 152 N., R. 97 W., where in a high bluff 100 feet of dark-gray till overlies 100 feet of soft Fort Union sandstone. This outcrop lies within the morainic area to be described later, which probably accounts for the exceptional thickness of the pre-Wisconsin drift at this point.
>
> Another excellent drift section occurs in this same morainic area 3 miles west and one-half mile south of Charlson, or 5 miles south of the Missouri River on a tributary of Sand

[23] Chamberlin, T. C., Preliminary paper on the terminal moraine of the second glacial epoch: U. S. Geol. Survey Third Ann. Rept., pls. 28, 35, 1883; The rock scorings of the great ice invasions: U. S. Geol. Survey Seventh Ann. Rept., pl. 8, pp. 155–156, 1888.

[24] Leonard, A. G., The surface features of North Dakota and their origin: North Dakota Univ. Quart. Jour., vol. 9, no. 3, map, 1919.

[25] Wilder, F. A., Lignite on the Missouri, Heart, and Cannonball Rivers and its relation to irrigation: North Dakota Geol. Survey Third Bienn. Rept., pp. 19, 40, 1904.

[26] Leonard, A. G., The pre-Wisconsin drift of North Dakota: Jour. Geology, vol. 24, pp. 524–526, 1916.

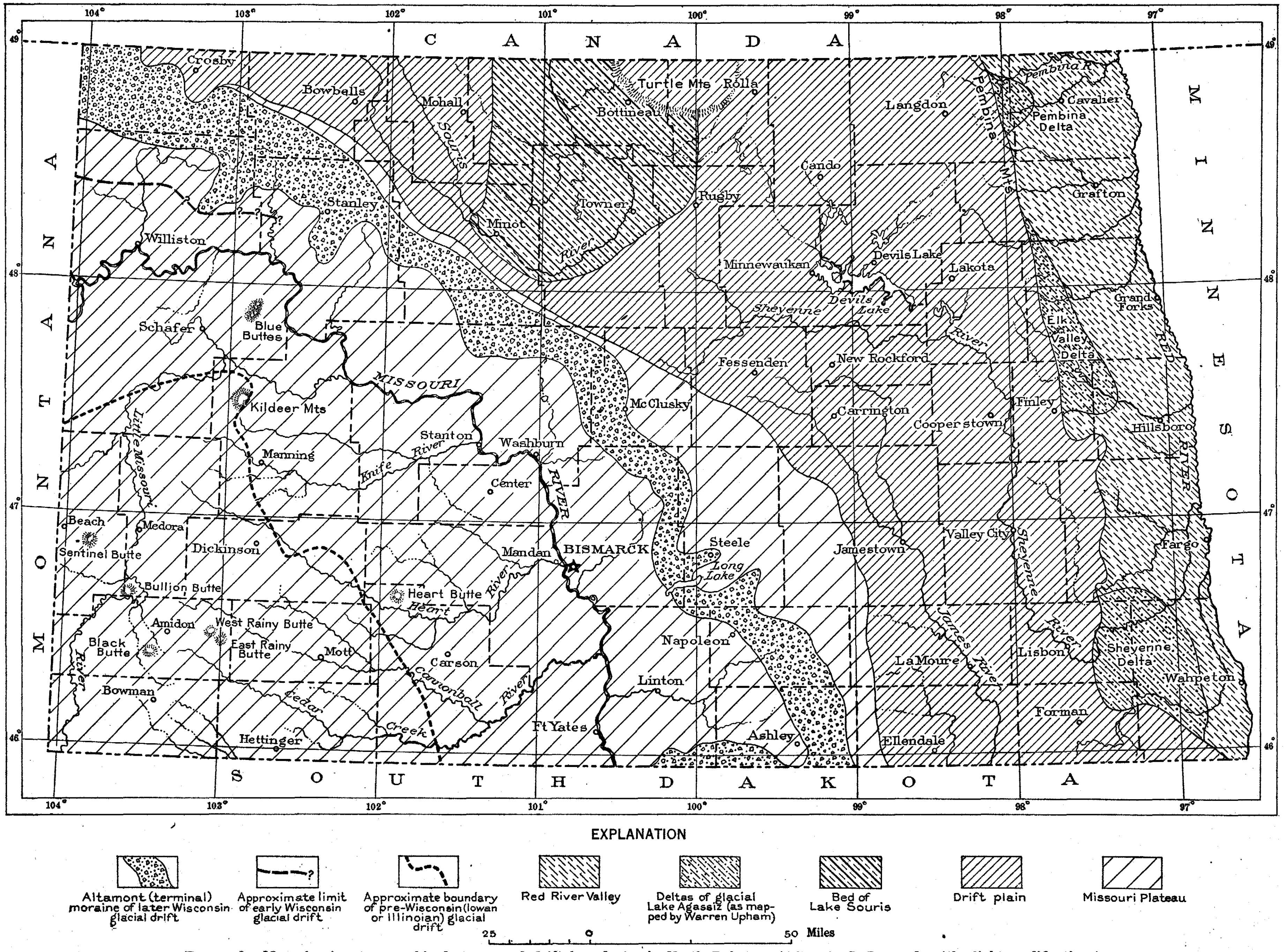


FIGURE 6.—Map showing topographic features and drift boundaries in North Dakota. (After A. G. Leonard, with slight modifications)

Creek. Here the following section appears in the steep bluff which rises abruptly from creek level:

	Ft.	in.
Sandy clay and soil	2	
Sand and clay in alternating bands	8	
Gravel		8
Sand and clay in alternating layers	3	
Gravel, coarse		8
Sand	2	4
Gravel	7	8
Till or boulder clay, dark gray in color, and containing large numbers of pebbles and boulders embedded in the tough, hard clay. A large proportion of the boulders and pebbles are composed of compact limestone and the till contains considerable blue shale (Pierre?). Thickness of till exposed above the creek	61	
	85	4

The sand and gravel forming the stratified drift of the foregoing section are light yellow in color. The drift hills just back of the bluff rise 50 to 60 feet above the top of the section, so that the total thickness of the drift above creek level is from 140 to 150 feet.

East of Tobacco Garden Creek there is in places considerable drift. Leonard [27] has described a moraine which is traceable in a southwesterly direction from the vicinity of the Missouri River bluffs near Davis Ferry, north of Charlson, in T. 153 N., R. 96 W., to a point 8 or 9 miles northeast of Schafer, in secs. 14 and 15, T. 151 N., R. 97 W. He states that it has a length of 16 miles, an average width of 2 miles, and an area of about 30 square miles. This moraine was traversed by the present writer in 1916 through about two-thirds of its extent and was also seen in 1921. It consists of an uneven ridge marked by sags and swells and carrying many crystalline boulders. East of Elidah its morainal character is very well marked. It is described by Leonard as follows:

This moraine shows well from Charlson, where its ridges and hills are seen rising from 100 to 150 feet above the flat plain in the foreground. Within the morainic area the surface is rough and hilly and the ground is thickly strewn with boulders. The topography is typically morainic, with numerous irregular hills and ridges, while scattered among the hills are great numbers of hollows or kettle holes, some containing water and others dry. Many of the hills rise 50 to 125 feet above the bottom of the kettle holes.

Where this moraine crosses the valley of Timber Prong Creek it forms a dam, which holds back the waters of the upper valley and forms a lake known locally as Dimick Lake. This moraine lake is very irregular in shape and has an area of between 2 and 3 square miles.

As will be noted from Figure 6, the approximate margin of the drift as mapped by Leonard loops about the east and north sides of the Killdeer Mountains with a fairly sharp angle. This appears to mark the junction of the Dakota and Montana lobes of the pre-Wisconsin (Iowan or Illinoian?) ice sheet. In a traverse made by the writer in October, 1921, scattered drift boulders were seen east of Watford City and north of Croff post office in Ts. 149–152 N., R. 96 W., but no glacial till was noted, although it is known to occur farther east between R. 96 W. and the north-south channel of the Missouri River, in the Fort Berthold Indian Reservation (p. 77). It is possible, therefore, that the interlobate angle really headed near or north of Blue Buttes. The southwestward trending moraine between Charlson and Watford City may thus be a terminal moraine on the northwest side of this angle, and the scattered outlying boulders may perhaps have been dropped from icebergs floating on ponded waters bordering the ice fronts. The writer offers this suggestion, but he has not himself made sufficiently detailed examination of the district to be sure that it is correct. Scattered boulders were also seen along the road south of Watford City to the gorge of the Little Missouri, but south of this none were noted on a traverse south past Grassy Butte post office, and east about the head of Charlie Bob Creek, in T. 145 N., Rs. 96–98 W., until a point was reached south of the Killdeer Mountains and within 5 or 6 miles west of the village of Killdeer. East of this are scattered drift boulders. In a tramp of about a mile on the south end of the top of the Killdeer Mountains, no drift was seen, and no drift is reported as found anywhere on the top by Quirke.[28]

A cut east of Dunn Center, on the Killdeer branch of the Northern Pacific Railway, examined by the writer in 1921, exposed 15 to 20 feet of very stony clay till. There is much included limestone here, and one block is 6 feet long. Among granitic boulders scattered on the surface, one 10 feet long was noted. Boulders were also seen scattered over the surface southward nearly to and east of Dickinson, on the Heart River.

In a report on the lignite in the western part of the Fort Berthold Indian Reservation Bauer and Herald [29] give the following description of the glacial deposits:

Both stratified and unstratified drift * * * cover large portions of the field and were noted in many localities. In general, however, their thickness is less than 5 feet, and in some places, particularly along the larger streams, they are absent. On Little Missouri River the effects of glaciation can hardly be detected, except for the presence of scattered foreign boulders. In the NW. ¼ sec. 27, T. 148 N., R. 93 W., and in the NE. ¼ sec. 23, T. 148 N., R. 92 W., there is some consolidated glacial drift, with a maximum thickness of 15 feet, containing numerous concretions and boulders of shale and sandstone, with a few boulders of granite and limestone. The whole is cemented by gypsum and iron oxide. Along the creek in sec. 7, T. 152 N., R. 93 W., the drift is 37 feet thick but unconsolidated, and at several places in the township to the west it was found to be as thick as 15 feet.

[27] Leonard, A. G., The pre-Wisconsin drift of North Dakota: Jour. Geology, vol. 24, pp. 527–528, 1916.

[28] Quirke, T. T., The geology of the Killdeer Mountains, North Dakota: Jour. Geology, vol. 26, pp. 260–261, 1918.

[29] Bauer, C. M., and Herald, F. A., Lignite in the western part of the Fort Berthold Indian Reservation, N. Dak., U. S. Geol. Survey Bull. 726, p. 114, 1922.

Leonard[30] gives the following description of a gravel deposit near Gladstone:

That a lobe of the ice sheet crossed the Heart River at Gladstone is shown by the presence of thick deposits of drift gravels on the upland 1 to 2 miles south of the Heart and at an elevation of between 100 and 200 feet above the river level. In places the gravel and sand have a thickness of at least 90 feet, and the deposit contains a number of good-sized granite boulders. A well-defined gravel ridge marks the edge of the drift for 3 or 4 miles in this area south of the Heart River at Gladstone. This ridge rises 30 to 40 feet above the surface on either side and falls away rather abruptly on the south, while on the north the slope is more gradual.

In 1921, when the Gladstone deposit was visited by the present writer, sand and gravel were being taken from a small pit near the top of the north slope. South of this is a larger excavation to which a spur track formerly led from the railway. These pits expose 10 to 30 feet of stratified cross-bedded sand and gravel, the pebbles in which more closely resemble the bench gravel along the Yellowstone River than the glacial drift. These pebbles range from less than an inch to 3 inches in diameter and consist principally of quartz, quartzite, and chert, with some agate and some dense dark and greenish crystalline rocks, diorite, and porphyry. None of the stratified material, so far as noted, is certainly glacial drift. There were about a dozen boulders of gray and pink granite gathered in a pile on the bottom of the pit, and these are probably of glacial derivation, but they may have rolled down from the surface during excavation of sand and gravel. The deposit appears to cap the ridge for some distance to the south and east. It is possible that this is an erosional remnant of a late Tertiary or early Pleistocene gravel bench similar to the benches on the Yellowstone River. If the granite boulders were actually interbedded with the sand and gravel, however, as intimated by Leonard, it is probably a glacial deposit. No glacial drift was seen by the present writer on a traverse extending about 9 miles south of Gladstone and thence east and north to Richardton nor along the main road and railway between these two places.

Some of the glacial drift of the Bismarck quadrangle was examined in 1911 by the writer, in company with Dr. Leonard, who describes the drift west of the Missouri River as follows:[31]

The most interesting and notable occurrence of glacial till in Morton County is found in the basin of the Little Heart River, where the drift has been heaped up into morainic hills. During the glacial period this basin was probably occupied by an ice lobe of the continental glacier, and this lobe formed the belt of morainic hills which nearly encircles the broad valley plain and deposited more or less drift in the preglacial valleys of the Little Heart and its tributaries. As the ice melted, the waters flowing from it deposited much outwash silt in the form of valley trains sloping away from the moraines. A number of the morainic hills have been partially buried by the outwash silt and rise like islands from the level plain of the valley train. The morainic belt of boulder-covered hills and ridges is found near the base of the slopes on either side of the two valleys tributary to that of the Little Heart River. Moraines cross the valley in three places, and one belt of ridges and hills continues unbroken along the south side of the valley of the South Branch for a distance of 12 miles. The cultivated fields extend up to the moraine and end there, where the soil becomes too rocky and the slopes too steep for cultivation.

Wilder[32] makes the following statement about drift west of the Altamont moraine:

On the Cannonball River the extreme western limit of the glacial drift seems to be about 10 miles west of the mouth of the Cedar River. For many miles east of this point the drift is represented only by boulders, which in places are quite abundant. * * * The boulders here, as everywhere near the edge of the drift, lie directly on Laramie clays. Beyond the drift, in the southern part of the State, particularly in the Cannonball country, fragments of quartzite, which is regarded as residual, are very abundant, often literally paving the hilltops.

PRE-WISCONSIN (ILLINOIAN OR IOWAN?) DRIFT NORTH OF THE MISSOURI RIVER

WILLIAMS COUNTY, NORTH DAKOTA

On the upland extending west and southwest of Ray to the Little Muddy Valley, till and boulders are generally present. The till is calcareous, and pebbles and boulders of limestone are included in it up to the top, and limestones also lie on the surface. Other erratics noted consist of granite, schist, and red quartzite. The slopes, except near the valleys, are generally long and smooth north of the dissected belt or "breaks" bordering the Missouri River. The valley of Little Muddy Creek is broad for 20 miles or more between the Missouri River and the morainal deposits south of Marmon. The region extending from the vicinity of this valley and latitude 103° W. westward to the Montana line has been examined and described by Herald.[33]

At Williston well-stratified fine gravel is exposed in an excavation at the east end of Main Street both east and west of Little Muddy Creek. Gravel was also seen at a few places farther north. Grayish calcareous till containing good-sized granite boulders is exposed in an excavation west of the railway station, not far above the level of the Missouri River.

The smoothly undulating plain of southwestern Williams County is in general moderately eroded, and the main valleys, such as that of the Little Muddy, Cow, and Painted Woods Creeks, are bordered by broad sloping benches like the bottoms of old valleys in which are sharper inner and younger valleys.

[30] Leonard, A. G., The pre-Wisconsin drift of North Dakota: Jour. Geology, vol. 24, p. 530, 1916.
[31] Idem, p. 523. See also U. S. Geol. Survey Geol. Atlas, Bismarck folio (No. 181), pp. 4–5, 1912.
[32] Wilder, F. A., Lignite on the Missouri, Heart, and Cannonball Rivers and its relation to irrigation: North Dakota Geol. Survey Third Bienn. Rept., p. 40, 1904.
[33] Herald, F. A., The Williston lignite field, Williams County, N. Dak.: U. S. Geol. Survey Bull. 531, pp. 91–157, 1913.

These benches and the upland slopes are rather sharply dissected by V-shaped branching coulees at the headwaters of the streams. Drift is generally present in the form of a thin sheet of till, with scattered boulders of red and gray granite, schist, and buff limestone. It is not clearly apparent how much of the minor dissection has taken place since the drift was deposited. It is clear that the main valleys, such as that of Little Muddy Creek, are older.

The amount of erosion appears to be about the same north of the outer disconnected line of morainal deposits, traced near Marmon, to the Altamont moraine, in which almost no erosion has been accomplished. As stated by Herald, the lower courses of the streams are in general marked by sharply cut valleys of considerable depth, whereas their upper parts flow through very broad valleys which merge into long gentle slopes extending to the divides. At some places the bluffs along the streams are abrupt, but along the north side of the Missouri near and west of Williston they give place to a general slope from the upland. Glacial till is found on this slope down to the railroad at Williston.

Although the main valleys undoubtedly have been glaciated, it seems probable that the minor sharp branching tributary ravines are postglacial. At least so far as seen they show little evidence of glacial modification. The narrow dissected belt bordering the Missouri east of Williston is well shown in the southern part of the Ray topographic map. There is here a maximum relief of about 500 feet.

THICKNESS OF THE ICE SHEET IN NORTH DAKOTA

Leonard[34] has made the following deduction concerning the thickness of the pre-Wisconsin ice sheet in western North Dakota:

> In the vicinity of Berg, in northeastern McKenzie County, there áre twelve or fifteen high buttes, known as the Blue Buttes, which are irregularly distributed over an area of 15 or more square miles. Many glacial boulders occur on top of these buttes at an elevation of over 2,700 feet above sea level, or 1,000 feet above the Missouri River only 6 miles to the east. Since the buttes rise nearly 500 feet above the surrounding upland the ice sheet probably had at least this thickness in order to override them and deposit boulders on their summits. Another explanation for the presence of the boulders on top of the high buttes is that the ice upon encountering these obstructions was buckled up as it passed over them. But it seems more probable that the ice sheet which was able to push across the deep valley of the Missouri River and advance 40 to 60 miles beyond was thick enough to submerge the Blue Buttes and pass on over them. The terminus of the continental glacier was not far from 15 miles south of the Blue Buttes, since the ice advanced only as far as the Killdeer Mountains. Back about 15 miles from the edge the ice sheet therefore doubtless had a thickness over the upland plain of considerably over 500 feet. The ice which filled the Missouri River Valley must have had locally a thickness of 1,000 feet or over.

[34] Leonard, A. G., Jour. Geology, vol. 24, pp. 530-532, 1916.

PRE-WISCONSIN (ILLINOIAN OR IOWAN?) DRIFT BORDERING THE MISSOURI RIVER IN MONTANA

DRIFT NEAR AND EAST OF GREAT FALLS

There is some difficulty in determining the exact southern limit of the Wisconsin drift on the plains of Montana. As far east as the eastern boundary of the Fort Belknap Indian Reservation the limit is fairly well defined and is approximately as mapped by Calhoun.[35] Farther east there is no continuous well-defined terminal moraine, and the numerous reconnaissance traverses made by the writer in 1916, 1920, and 1921, together with such examinations as have been made by other geologists, have not yielded definite results as to the location of this boundary. There is good reason for thinking that there was at least one incursion of the Keewatin glacier on the plains of Montana prior to the Wisconsin stage of glaciation, and to this earlier advance is probably to be referred the glacial drift south of the Missouri River in Montana and North Dakota and also some of that north of the river. The location of the limit of the Wisconsin drift as shown on Plate 1 is largely hypothetical. (See p. 96.) The drift south of this hypothetical boundary (see p. 69) is tentatively correlated either with the Illinoian drift or with the Iowan drift of northeastern Iowa. Although this correlation may be open to question, the terms Illinoian or Iowan (?) ice sheet and Illinoian or Iowan (?) drift are used here for convenience of description.

The Missouri River had reached its lowest level of erosion by the time the advancing Illinoian or Iowan (?) ice front reached the old valley between Great Falls and Havre and eastward along the course now followed by the Milk River below Havre. (See pls. 1, 29.) There had also been deposited in this valley a certain amount of filling of nonglacial river gravel. (See p. 68.) As the ice advanced it deposited more or less till upon the gravel and probably pressed forward against the north and west flanks of the Bearpaw Mountains, as did the later ice of the Wisconsin stage. It crossed the preglacial valley of Marias River and the Teton and Missouri Valleys and crowded up on the benches bordering the north base of the Highwood Mountains to a level which is now about 3,600 feet above the sea. It overtopped Shepard Butte, west of Waltham, and on melting left boulders scattered on the surface where now is the triangulation post of the Missouri River Commission, at an altitude of about 3,800 feet (barometric). This is about 1,000 feet above the present level of the Missouri River at the mouth of Belt Creek, 5 miles to the west. Passing this butte it advanced up the old Missouri River Valley to a point about a mile north of Gerber

[35] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, pl. 1, 1906.

and left therein a great deposit of drift completely filling the valley. It crowded up on the edge of the upland to the east near the line of the Great Northern Railway to an altitude of 3,600 feet. (See fig. 10, p. 92.) Here the glacial boulders may be seen scattered over the surface of the bench gravel.

Northeast of Great Falls the Great Northern Railway crosses the river above Rainbow Falls and climbs the slope to the upland on the north. In the cuts near the top of the slope, south of Goodale, the Cretaceous shale is overlain by about 30 feet of dull-grayish pebbly clay till. In the first cut south of the Big Falls road the till is overlain by 8 feet of dark to black laminated clay, somewhat distorted in places. This lacustrine clay is about 400 to 500 feet above the level of the river below Big Falls. The till extends down the slope to the rim of the gorge, about 180 feet above the river below the falls. (See pl. 31 *B*.)

The dull-grayish till was also well exposed when seen in 1920, 1921, and 1922, in numerous cuts along the line of the Chicago, Milwaukee, St. Paul & Pacific Railway between Great Falls and Highwood Creek. Some of these cuts are more than 100 feet deep and yet do not reach the base of the drift in the part where the railway crosses the buried valley of the Missouri River. Where the main road east from Great Falls to Highwood crosses Red Coulee, scarps due to slumping expose in places 50 feet or more of dull-gray till over red to purplish Kootenai shale. In places chunks and stringers of the red shale have been dragged up into the till. One scarp south of the road exposed the following section:

Section of drift in Red Coulee east of Great Falls

	Feet
3. Dull-gray pebbly clay till	15
2. Stratified dark clay, partly like papery shale, partly pebbly	1-3
1. Dull-gray pebbly clay till, with included masses of red shale	5

This exposure is near the southeastern limit of the glacial drift, and No. 3 may have been deposited when the ice readvanced, pushing forward over the silt (No. 2) deposited in the marginal glacial lake described on page 88. Nos. 1 and 3 are probably not of greatly different age.

What may be a thin deposit of Illinoian or Iowan (?) till is exposed in the bluff below the railway near the river bend west of Fort Benton. (See No. 3 of section on p. 66.) It overlies nonglacial stream gravel and is covered by wind-blown silt beneath the later drift.

About 100 feet of dull-gray clayey till, with few pebbles, is exposed in bluffs along the lower course of the Teton River. At the railway tunnel the narrow dividing ridge between the Teton and Missouri Rivers is nearly cut through. This ridge appears to be mostly drift filling the former course of the river, which had cut down nearly or quite to its present level. In places near Teton station there is a bed of gravel between the base of the till and the top of the underlying shale.

Bowen[36] has mapped the boundary of the drift for about 25 miles along the west foot of the Bearpaw Mountains in the Big Sandy coal field. He writes about the drift as follows:[37]

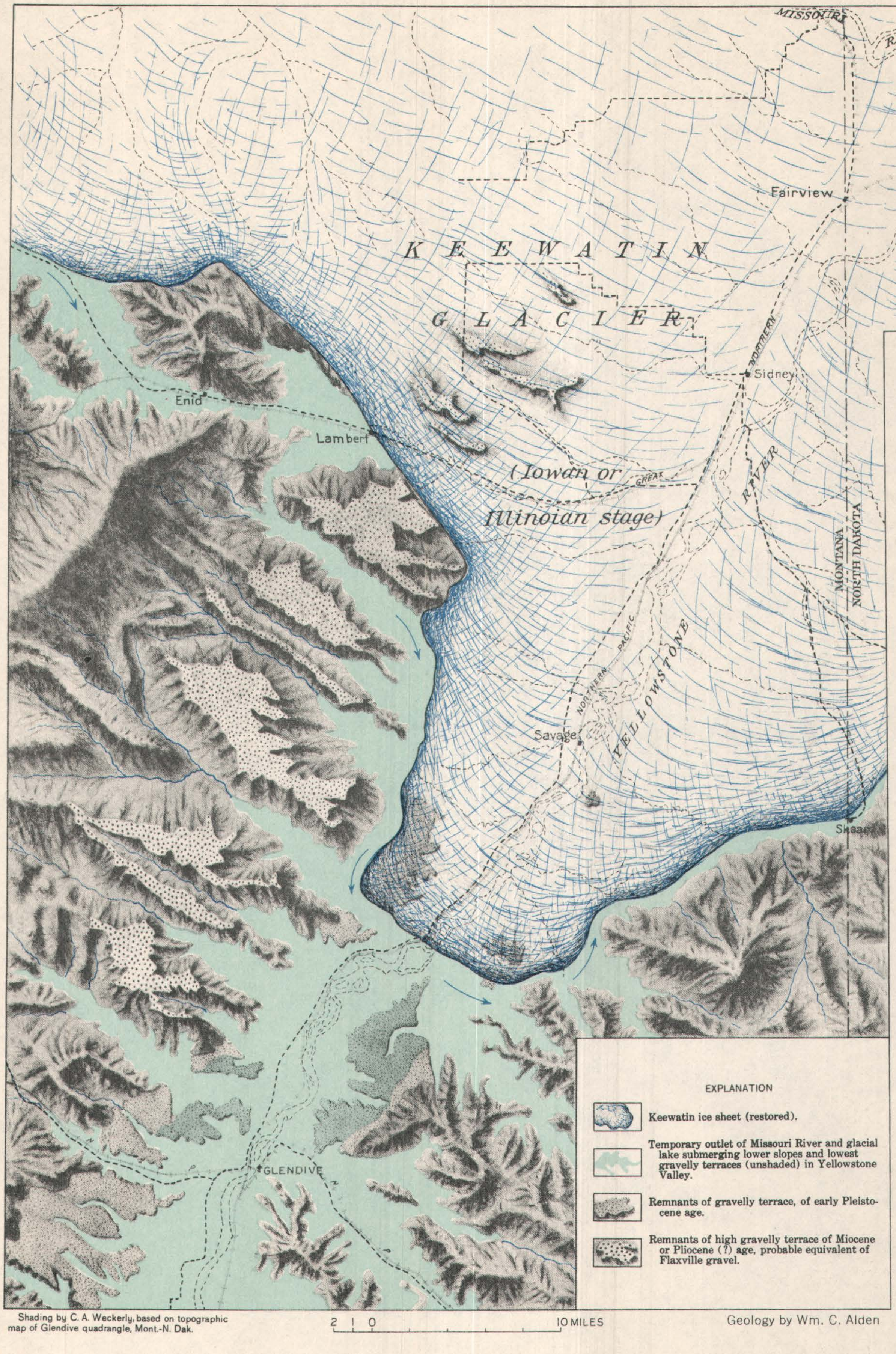
> Over most of the district the drift consists of a heterogeneous mixture of sand, gravel, and boulders, variable in size and in lithologic character. The most numerous and conspicuous erratics are granites, gneisses, and quartzites that obviously have been transported from distant regions, inasmuch as they are totally unlike any rocks occurring in place in this part of Montana. Along Missouri River and its tributaries, however, the bluffs are capped by a deposit of light-yellow, partly consolidated loesslike sand and clay which is in places apparently stratified and as a rule contains a few small waterworn pebbles. This deposit is doubtless due to some phase of glacial action.

Similar loamy clay was seen by the writer in 1920 overlying the 10 feet of gravel which caps the bluff of sandstone and shale on the southeast side of the Arrow River opposite the mouth of Steele Creek, at the east end of the Shonkin Sag. The loamy clay looks like wind-blown material, as it is heaped up in a small ridge along the crest of the bluff. Calhoun[38] found the drift extending as far eastward along the Missouri River as the mouth of the Arrow River. The east limit of the drift for about 20 miles north of the river is as mapped by Reeves.[39]

The relations of the glacial front and the drift deposits to the Bearpaw Mountains were probably much the same at the Illinoian or Iowan (?) stage as at the Wisconsin stage. (See pl. 29.)

No evidence of pre-Wisconsin drift was noted by the writer about the north side of the Bearpaw Mountains nor in the area between the Bearpaw and Little Rocky Mountains. (See pl. 1.) The same is true with regard to the north flank of the Little Rocky Mountains, at least as far east as the vicinity of Lodgepole Creek. The maximum height of land overridden by the marginal part of the Wisconsin ice sheet appears to be quite definitely shown by the limit of the drift sheet on No. 1 bench east and west of the road leading north from Lodgepole. In the N. ½ sec. 25, T. 7 N., R. 23 E., the limit is 3,500 feet above sea level. It is about 3,550 feet near the middle of the south line of sec. 19 and also in the NE. ¼ NW. ¼ sec. 28, T. 27 N., R. 25 E. Scattered drift pebbles and boulders were noted

[36] Bowen, C. F., The Big Sandy coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 541, pl. 21, 1914.
[37] Idem, p. 365.
[38] Calhoun, F. H. H., op. cit., p. 44.
[39] Reeves, Frank, Geology and possible oil and gas resources of the faulted area south of the Bearpaw Mountains, Mont.: U. S. Geol. Survey Bull. 751, pl. 13, 1924.



MAP OF THE GLENDIVE QUADRANGLE, MONT., SHOWING THE RELATIONS OF THE KEEWATIN ICE SHEET OF THE IOWAN OR ILLINOIAN (?) STAGE OF GLACIATION TO THE YELLOWSTONE VALLEY AND THE REMNANTS OF THE GRAVELLY BENCHES OR TERRACES somewhat farther south on the bench east of the Lodgepole road and also up to the top of the Judith River sandstone ridge (altitude 3,650 feet) which extends southeastward from the gorge of Warm Springs Creek, in the SE. ¼ sec. 1, T. 26 N., R. 25 E., into the SW. ¼ sec. 27, T. 26 N., R. 26 E., though the Wisconsin terminal moraine appears to lie on the lower land to the northeast. Drift boulders of granite and quartzite pebbles are also sprinkled over the bottom of the valley southwest of the sandstone ridge and even on the gravelly top of No. 2 bench to the south and west nearly up to an altitude of 3,650 feet near the base of the mountain wall. One of the granite boulders seen on this bench measured 3 by 4 by 6 feet. Though it is possible that the foreign pebbles and boulders on the lower ground might have been dropped from icebergs floating on water ponded between the front of the Wisconsin ice sheet and the mountain flank, it is not evident how those at the higher levels could have been so transported, because so far as known to the writer there is no ridge sufficiently high south of the Judith River sandstone ridge and east of the mountain wall, unless it be away off south of the Missouri River, to have ponded water in such a marginal glacial lake up to an altitude of 3,600 feet or even 3,500 feet. Drift pebbles and boulders were found scattered on the lower slopes and benches surrounding the buttes in and near the southeastern part of the Fort Belknap Indian Reservation up to 3,550 feet. No drift was found on the top of Middle Butte, which rises 600 to 700 feet above No. 2 bench, to 3,950 feet. On the top of East (Coburn) Butte, however, there were in July, 1921, scattered quartzite pebbles and one granite boulder measuring 2 by 3 feet. This was just south of the boundary post at 3,720 feet. This boulder is 200 feet higher than the upper limit of the Wisconsin drift on No. 1 bench north of Lodgepole, 15 miles farther northwest, so that there is little likelihood that it was placed here by the Wisconsin ice sheet, and much less that water was ponded sufficiently high for it to have been dropped from floating ice. In September, 1916, the writer found a quartzite pebble on the top of West Butte, in sec. 31, T. 25 N., R. 26 E., but no drift was seen either on the sandstone ridge between West Butte and Bear Gulch Creek or on No. 1 bench or the lower areas near the south side of the mountains farther west. It seems probable that some at least of the foreign pebbles and boulders scattered in the places noted were brought to their positions by an earlier and more extensive glacier. (See pl. 29.)

Glacial pebbles and boulders were found sprinkled over the surface of the shale along the road from sec. 22, T. 24 N., R. 25 E., about 6 miles south of Zortman, to the breaks north of the Missouri River near Wilder, but no glacial till was seen. Such pebbles and boulders are also scattered westward in Rs. 24 and 25. Calhoun's map [40] shows the west limit of this drift as near the mouth of Cow Creek, which is in sec. 8, T. 23 N., R. 22 E., and crossing thence to the area south of Missouri River. In 1921 Frank Reeves mapped the approximate limit of this drift as shown in Plate 1—that is, southward through Ts. 21 to 23 N., R. 21 E., and eastward through T. 19 N., Rs. 23 to 29 E., and south through T. 18 N., R. 29 E. Reeves states [41] that the foreign pebbles and boulders were found scattered between this limit and the Missouri River but no glacial till was seen overlying the Cretaceous shale and sandstone. Reeves also reports the presence of gravel on a ridge about 18 miles north of Roy, in T. 21 N., R. 22 E., but it was not determined whether this is glacial drift or a remnant of the bench gravel. The present writer found the outermost glacial pebbles and boulders 24 miles northeast of Winifred, in T. 23 N., R. 21 E., and about 11 miles northeast of Roy, in T. 19 N., R. 23 E., but saw no till.

C. F. Bowen informed the writer that in the course of a traverse of the country between the Judith and Musselshell Rivers in 1912, he saw an erratic granite boulder in T. 16 N., R. 28 E., about 15 miles northeast of Winnett.

DRIFT EAST OF THE MUSSELSHELL RIVER

In August, 1921, the writer found boulders of red and gray granite scattered upon the bench west of the Musselshell River near Mosby and southward to the valley of Boxelder Creek. The granitic pebbles overlie the bench gravel, but none were seen intermingled with it.

Glacial pebbles and boulders were seen by the writer in 1921 in Garfield County, within a few miles northeast of Mosby, on the east side of the Musselshell River on the road to Sand Springs, and also on the South Fork of Lodgepole Creek below Tindall, in and below sec. 32, T. 18 N., R. 31 E. These consist principally of granite and other crystalline rocks, limestone, and quartzite. The region is very rough and much dissected. C. E. Dobbin [41] in 1921 found such erratics scattered from this locality northward to the Missouri River as mapped by Calhoun, but he did not find any east of Devil Creek, in Ts. 21 and 22 N., as far east as Hell Creek, in R. 37 E., nor did he find any glacial till south of the Missouri River. No erratics were seen by the writer on traverses between Jordan, Chalk Buttes, Hazny, and Edwards.

W. T. Thom, jr.,[41] in 1921, found a 2 by 3 by 1½ foot granite boulder about 15 miles south of Sand Springs, in sec. 9, T. 13 N., R. 34 E. This gives rise to the suggestion that some, at least, of the scattered

[40] Calhoun, F. H. H., op. cit., pl. 1.
[41] Personal communication.

glacial pebbles and boulders may have been transported by ice floating on water ponded in front of the ice sheet as it lay along or near the present course of the Missouri River and that there may have been an outlet for this lake southeastward from the Musselshell Valley to the Yellowstone near Forsyth. There must have been a great deal of water flowing eastward or southeastward somewhere through this region for a time, for all the drainage of that part of the upper Missouri Basin outside the margin of the ice sheet, together with water from the glacier itself, must have had an outlet to the Yellowstone. The absence of any known glacial till south of the Missouri River within this tract makes it somewhat questionable whether or not the ice lobe between the Little Rocky Mountains and the Larb Hills on the east extended southward beyond the present line of the Missouri. It may be noted, however, that neither have lacustrine clays, such as are present in the region of Great Falls, been observed in the tract described above. There is no question that the ice between the Little Rocky Mountains and the Larb Hills advanced nearly if not quite to that part of the Missouri's present course here under discussion.

Thicknesses of 15 to 50 feet of dull-buff to dark-gray pebbly clay till were observed either by A. J. Collier or the writer all along Beaver Creek, in southern Phillips County, between the Fort Belknap Indian Reservation and the confluence of Beaver and Flat Creeks, in T. 27 N., R. 32 E., and by the writer on Telegraph Creek about 10 miles north of the Missouri River, in the southeastern part of T. 24 N., R. 31 E. In 1920 Collier observed glacial boulders on the highest part of the Larb Hills, about 3,100 feet above sea level. Boulders were also observed by the writer in 1916 in the valley which transects the Larb Hills and is continuous from the head of Larb Creek to Timber Creek, also along the road from Carpenter's ranch, in T. 23 N., R. 35 E., in southwestern Valley County, northeast to Glasgow, and boulders and some till were seen along the road from Glasgow south to Lismas Ferry. Glacial boulders occur in northeastern Garfield County south of the Missouri River scattered along the valley of Dry Creek and over the upland to the west as far along the road from Haxby post office toward Jordan as the head of Flat Creek, in or near the southeastern part of T. 22 N., R. 40 E. (Patterson's ranch).

In 1919 and 1920 W. T. Thom, jr.,[41] examined the northern part of what is now McCone County, south of the Missouri River and east of Dry Creek. C. E. Dobbin also examined part of McCone County in 1922. Thom reports numerous exposures of glacial till, 20 to 30 feet in thickness, over shale and sandstone, so that the ice unquestionably extended south of the Missouri gorge in this tract. A part of this area was traversed by the writer in 1916 and again in 1920. Glacial pebbles and boulders of limestone, granite, and other crystalline rocks and quartzite are scattered over the whole area, at least as far south as T. 23 N. The till where seen is dense calcareous gray clay, containing few pebbles and cobbles. In places, as south of the Wolf Point Ferry, nearly 50 per cent of the pebbles and boulders are of limestone. With these are quartzite, gray and red granite, diorite, diabase, and other crystalline rocks. One granite block 8 to 10 feet long was noted. These erratics are sound and show little evidence of long exposure to the weather.

Glacial boulders were found scattered eastward in T. 24 N. to and across the divide at the head of West Charley Creek, in R. 53 E. (See Glendive topographic map.)

DRIFT ON THE LOWER YELLOWSTONE

Boulders were not noted along the Richey branch of the Great Northern Railway through the pass between Lambert and Enid, nor for 8 or 9 miles north of Enid. The ice, however, evidently overtopped the hills and high benches as far south as the railway in Fox Creek Valley between Lambert and Gettysburg station, where there are boulders. (See pl. 28.) In 1921 thin glacial till and boulders were observed by the writer between the Yellowstone and a line passing through Three Buttes, Lone Butte, and Sioux Pass.

A low ridge at the north edge of the high No. 1 bench south of Lambert and 450 feet above the village looks like a small morainal ridge and suggests that possibly the ice may, at its maximum, have filled Fox Creek Valley and banked against and barely overtopped the slope to the south. Where examined the ridge consists of buff clay inclosing pebbles as much as 6 inches in diameter. The fact that the pebbles are mostly quartzite and quartz and that none were found of limestone or granite, such as are characteristic of the glacial drift, however, makes it doubtful if the ice really reached the edge of the high bench. It is clear, nevertheless, that the glacial front extended around the east end of the high bench and that a lobe of ice extended up the Yellowstone Valley for a distance of 25 miles south of the Fox Creek Valley—that is, to the vicinity of the United States Bureau of Reclamation dam at Intake (shown on the topographic map as "Headworks"), about 18 miles below Glendive. Abundant glacial boulders of red, pink, and gray granite and limestone, 1 to 5 feet in length, are found scattered over the slopes and middle benches (early Pleistocene) as high as 500 feet above the river, or about 2,450 feet above sea level.

The presence of a few small granite boulders on the end of the high bench 10 miles west of Burns, 800 feet above the river, or 2,000 feet above sea level, leads to the suggestion that the ice may perhaps at first

[41] Personal communication.

have crowded against the end slope of the ridge and overtopped it. There is a possibility, however, that these stones may have been hauled up from the lower bench to the east, as they were seen near other stones that had evidently been collected for the purpose of making a foundation for a building. No other granites were seen on this bench in the course of a 10-mile traverse.

Several small granite boulders and a block of limestone measuring 3 by 3 by 6 feet were observed by the writer on No. 2 bench west of the river about 6 miles north of Glendive, and similar erratics were found scattered over the correlated bench east of the river known as Belle Prairie. These were probably dropped from icebergs floating on a lake held in the Yellowstone Valley when the front of the glacier blocked the valley at Intake. During the examination of the Sidney lignite field, in 1910, Stebinger [41] found a large glacial boulder of crystalline rock on the upland between Smith and Dry Creeks, east of Burns, in T. 19 N., R. 58 E., and in 1921 the writer found boulders scattered most of the way along the road east and northeast from Intake to Skaar post office, near the State line on upper Smith Creek in southeastern McKenzie County, N. Dak.

Brown [42] states that glacial drift is abundant between the Missouri and Yellowstone Rivers and on ridges near the Yellowstone is several feet thick, also that near the Missouri River the drift is more eroded and only large boulders remain. Apparently Brown included some of the nonglacial gravel under the term "drift," or at any rate, the statement is ambiguous, as no southern limit is given for the district described. With the exception of a boulder seen by W. T. Thom, jr., 15 miles south of Sand Springs and another seen by Thom in the Redwater Valley near Circle and of what appeared to be glacial till observed by A. J. Collier in 1928 northeast of Circle, in sec. 14, T. 21 N., R. 49 E., no glacial drift has been reported to the writer as found south of the limit noted above and shown on the map.

In McCone County two well-marked cycles of topographic development are represented, one a mature erosion topography with long slopes. In places, as southwest of Nickwall, in the southeastern part of the Chelsea quadrangle, this has been but little modified, being represented by a broad abandoned valley with long side slopes. This valley extends north from Redwater Creek to the Missouri. Its bottom, a poorly drained flat about 1 mile in width, lies about 2,015 to 2,020 feet above the sea, or 40 to 50 feet above the Missouri River bottom land. Back from the valley the long smooth upland slopes are but little dissected and are largely under cultivation. Rather generally, however, in the area traversed south of the Missouri the slopes of this older topography bordering the valleys are sharply dissected by branching V-shaped coulees of a later cycle, which represent the topographic development since the region was glaciated and give the "break" along the Missouri and in places badland tracts. The later slopes are largely bare shale and sandstone, and the pebbles and boulders on them appear to have been let down by erosion of the upland deposits. The drift in the larger valleys, however, appears to be as left by the ice—that is, deposited since the main drainage lines were eroded.

PRE-WISCONSIN (ILLINOIAN OR IOWAN?) DRIFT IN VALLEY AND ROOSEVELT COUNTIES, MONT.

South of the broad basin in which lies Medicine Lake, a smooth plain marking the position of Bauer's "Tertiary" valley (see p. 21), the surface rises gradually toward the south in the direction of the Missouri Valley. This belt east of Big Muddy Valley is underlain by the shale, sandstone, and lignite beds of the Fort Union formation, with red clinker formed by burning of the lignite. It is considerably dissected by short tributaries of the Missouri. From the crest there is a slope to the top of the steep, irregular bluff bordering the abandoned valley of the Missouri, which is traversed by the Great Northern Railway from Culbertson east to Bainville and thence south to the present valley at Lakeside. Similar irregular bluffs, or in places smoother steep slopes, bound the large island-like upland, 250 to 350 feet high, which lies between the old valley and the present valley. Near the head of Riprap Coulee, a few miles southeast of Lakeside, the highest hilltops are from 400 to 500 feet above river level. The topography of the belts bordering the Missouri on both the north and the south contrast strikingly with the broad plain and long, smooth slopes of the preglacial valley to the north, though the total maximum relief is not greatly different.

Beekly [43] maps the Fort Union beds as generally concealed by glacial drift on the uplands. He states that the drift in this area ranges from a thin film to a deposit 25 feet thick where exposed in sections on eroded slopes. Crystalline boulders are frequently seen but they are not abundant. Northeast of Bainville there seems to be considerable drift present, and the lowland between the bluffs shows an undulating topography. Evidently the area was occupied by ice since the old valley traversed by the railway was excavated.

Smith, who examined the old Fort Peck Indian Reservation, covering the area between the Big Muddy

[41] Personal communication.

[42] Brown, Barnum, The Hell Creek beds of the Upper Cretaceous of Montana: Am. Mus. Nat. Hist. Bull., vol. 23, p. 824, 1907.

[43] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, p. 321, 1912.

Valley on the east and Porcupine Creek on the west, together with two tiers of townships south of the Missouri River and northward to the old reservation line in T. 33 N., describes the topography as follows:[44]

North of the river for a distance of 15 to 20 miles the slopes are as a rule gentle and, with a few exceptions, the valleys are broad with gently sloping sides. Farther north the relief becomes bolder and the large streams are in places bordered by abrupt escarpments and hills ranging in elevation from 200 to 500 feet. The interstream areas are usually broad and flat.

In the north-central part of the reservation, south of Poplar River and Cottonwood Creek, is a gravel-covered terrace about 300 feet above stream level, which slopes gently to the southeast. A remnant of a similar terrace appears in the highlands north of Cottonwood Creek [the Flaxville Plain, bench No. 1].

South of Missouri River bluffs and hills rise abruptly from the edge of the flood plain to an elevation of several hundred feet. Near the river the topography is rough and in places the country is dissected into badlands, but farther to the south the badlands blend with rolling prairies of low relief.

The entire field considered here lies within the area once covered by the great continental ice sheet, whose effects on the topography are everywhere evident. Preglacial streams have been caused to abandon their channels, which now appear either as broad depressions containing intermittent lakes or as broad valleys occupied by streams of insignificant size. The movement of the glacier over the region has no doubt had a tendency to smooth away preexisting inequalities of the surface, and the retreating ice sheet has left a mantle of drift which has protected underlying formations from the erosion into badland forms common in regions not so protected. South of Missouri River evidences of glaciation are not so marked as they are north of the river.

The topography of most of this area is shown on the maps of the Porcupine Creek, Spring Creek, Todd Lakes, Tule Valley, Cuskers, Hay Creek, Smoke Creek, Homestead, Nashua, Frazer, Oswego, Wolf Point, Chelsea, Poplar, and Brockton quadrangles. Concerning the glacial deposits in this area, Smith writes[45]:

Overlying the greater part of the field is a mantle of glacial material of varying thickness, made up principally of igneous boulders and clay but containing some fossiliferous limestones. These boulders vary in size from mere pebbles to masses weighing probably 20 tons. It is probable that this drift formerly covered the entire region like a huge blanket, but stream action and weathering agencies subsequent to the retreat of the continental ice sheet have cut deep channels through the drift and into underlying formations.

That part of the old Fort Peck Reservation lying in Roosevelt County south of the Cottonwood Creek Valley and T. 32 N. and extending to the Missouri River shows little evidence of morainal deposits that can be regarded as marking the southern limit of the Wisconsin drift. A lobe of the Wisconsin ice sheet may have occupied the Big Muddy Valley and the preglacial valley west of Manning Lake about as far south as that lake. The unpublished field notes of C. M. Bauer's party cite numerous exposures of glacial drift ranging in thickness from 1 foot to 42 feet. The thicker of these may belong with the later deposits cited below. At one place west of Homestead, in T. 31 N., R. 55 E., the partial consolidation of several feet of drift suggested pre-Wisconsin age. The relations of the drift to the topography show, however, that it was deposited after mature erosion of the Flaxville gravel plain (No. 1) bench), which developed the long old valley slopes and No. 2 bench, and even after these had been dissected by the Missouri and its main tributaries.

Some of the slopes, such as that of the west side of the Poplar Valley, for example, have been considerably modified since the ice covered the region. Only scattered drift boulders, mostly of crystalline rock but some of limestone, appear on the grassed slopes, though these are well sprinkled with quartzite pebbles derived from the Flaxville gravel. Between the valleys and the sharply cut coulees the upland slopes are smooth and very gently undulating.

Some scattered drift knolls occur 8 to 10 miles north of Chelsea, in the Boxelder Creek Valley in T. 29 N., R. 49 E. These lie on the flat or lower part of the long slope which extends down to the sharp-cut inner valley. West of this occur the big boulders and morainal knolls described below. The Todd Lakes, about 16 miles north of Oswego, lie in a small transverse gorge due either to stream capture or to the discharge of glacial waters. The triangulation station north of this gorge, in the NW. 1/4 sec. 26, T. 30 N., R. 44 E., is on a kamelike knoll of quartzite gravel.

The intricate dissection of the slopes along parts of the Wolf Creek Valley and the valleys farther west is probably due to the fact that the sandstone is higher in the slopes than farther east and has been cut away from most of the area west of Little Porcupine Creek in Valley County, so that the soft shale is more readily eroded. The Little Porcupine Creek Valley is cut to a depth of 300 feet below the Flaxville Plain (No. 1 bench). This valley and the pass to the Cottonwood Creek Valley at its head probably constituted an outlet for much glacial water at one stage (possibly early Wisconsin). The steep irregular slopes of this valley in Ts. 30 and 31 N. are in striking contrast with the long smooth slopes of the glaciated upland. Crystalline boulders are sparsely scattered over the uplands west of Little Porcupine Creek, but there is little other evidence of glaciation. Quartzite pebbles derived from the Flaxville gravel are everywhere present.

A rather striking combination of old and newer topography was seen near the heads of Bear and Lime Creeks, 18 to 25 miles north of Tampico. Here the uplands are marked by long smooth benches sloping southward. These are cut diagonally across at the west and northwest by an escarpment below which to the west is a semibadland topography. The youthful

[44] Smith, C. D., The Fort Peck Indian Reservation lignite field, Montana: U. S. Geol. Survey Bull. 381, pp. 40–41, 1910.
[45] Idem, pp. 43–44.

tributaries of Rock and Willow Creeks are here cutting headward into the side of an older drainage topography.

Drift is generally present, though thin and largely composed of local material. Even the steep Recent slopes of nearly bare shale and sandstone are sprinkled with pebbles of quartzite and some of crystalline rocks, but these were let down from the higher levels by erosion. Here and there limestone boulders also occur.

West of Rock Creek the combination of long old upland slopes cut by later eroded valleys continues. The quartzite pebbles abound everywhere, though no remnants of the Flaxville Plain (No. 1 bench) with the deposits in place are preserved.

The writer observed till and boulders southwest of Glasgow, and Collier found glacial boulders even on the highest parts of the Larb Hills, 3,100 feet above sea level.

AGE OF THE DRIFT BORDERING THE MISSOURI RIVER

The character and relations of the glacial drift in northern McKenzie County, N. Dak., and in the Missouri River gorge have considerable significance in regard to the age of the pre-Wisconsin drift. Leonard [46] states:

The topography of the older drift and the large amount of erosion it has suffered compared with the Wisconsin till have been mentioned on a previous page, where it was shown that in many places only the coarser materials of the drift—the pebbles and boulders—remain as evidence that the ice sheet once covered the region. But the color of the pre-Wisconsin till is generally unlike that of the Wisconsin drift. The latter is commonly light yellow to light gray in color as exposed in railroad cuts or along stream valleys, but where the deeper till appears in fresh excavations it is seen to have the blue color of the unoxidized clay. The pre-Wisconsin till, on the other hand, where best exposed on Sand and Clear Creeks in northeastern McKenzie County, is dark gray in color throughout the maximum observed thickness of over 100 feet.

Except in the morainic areas the thickness of the pre-Wisconsin drift is not great. West of the Missouri River it is seldom as much as 8 or 10 feet, and generally the thickness is not over 2 or 3 feet or less. The thinness of the older drift is due partly to erosion, which has removed much of the glacial material and over a large part of the area left only boulders or a thin veneer of gravel, but partly, perhaps, also to the fact that the drift may never have been very thick in this region.

Leonard has called attention to the presence of glacial drift in the Missouri River gorge as evidence that this gorge is of preglacial age. He writes [47]:

There is abundant evidence that the Missouri Valley below the mouth of Snake Creek is preglacial, and that the river was not forced by the ice sheet to take its present southerly course through North Dakota. This evidence is based on the presence of glacial boulders on the valley bottom and at many points on a terrace representing a former flood plain of the Missouri. Boulders have been encountered in two wells in Bismarck at a depth of 125 feet below the surface, or 80 feet below river level. These wells are near the edge of the terrace bordering the Missouri Valley at Bismarck, and since the boulders rest on the bedrock they indicate that the valley was excavated to this depth prior to the glacial period. In several borings made for the Northern Pacific Railroad previous to the building of its bridge across the river at Bismarck from 70 to 80 feet of silt and gravel were passed through before reaching the bedrock, and in one boring a boulder was struck at a depth of about 50 feet below the river bed.

On the west side of the Missouri Valley, between Mandan and the mouth of the Knife River, there is a well-developed terrace which in places is a mile and more wide. This terrace has an elevation of 55 to 60 feet above the river, and the upper portion of it is in many places composed of glacial gravel and good-sized boulders. A railroad cut in this terrace a mile northeast of Mandan, near the cemetery, shows the following section:

	Ft.	in.
Soil	2–3	
Boulders and gravel	5–9	
Sand, finely laminated, with several thin layers of gravel	2–5	
Boulders and pebbles		6–12
Lance beds, exposed above railroad track	15	

In another cut less than one-quarter of a mile south a bed of boulders, many of them several feet in diameter, mixed with gravel and resting on the Lance beds, extends a distance of at least 100 yards along the railroad.

Several miles south of Price the upper part of the terrace is composed of boulders and coarse gravel, the deposit having a thickness of 5 to 6 feet. Between Sawyer and Price the terrace is finely developed and is covered in some places by a layer of gravel and boulders, in other places by unstratified glacial drift or boulder clay. In the vicinity of Hensler the Missouri Valley is several miles wide, and here, as well as in other places, numbers of low rounded drift hills, covered with numerous boulders, rest on the valley floor. Some of the railroad cuts show the boulder clay to be 30 to 40 feet thick.

Before the time of the earlier ice invasion, when the ice sheet advanced 40 to 50 miles beyond the Missouri River, that stream must have flowed in its present broad, terraced valley, and on the floor of this valley the glacier deposited the boulders, gravel, and till so well exposed at many points. These deposits, shown in the railroad cuts of the terrace, lie about 40 feet above the ordinary stage of the river and vary considerably in thickness.

Additional evidence that the present valley is preglacial and that the trench of the river was excavated to its present depth at the time of the earlier ice invasion is shown by the boulder bed less than half a mile below the mouth of Tobacco Garden Creek. This bed of boulders, which lies just above river level, is at least 12 to 14 feet thick and extends along the water's edge for a distance of 100 yards, while scattered boulders and ferruginous gravel occur at intervals for another 200 yards. Overlying the boulders are 15 feet of gravel. While some of the boulders of this deposit may have been brought here by floating ice, it is probable that most of the deposit was left here by the pre-Wisconsin ice sheet when it advanced south of the river. The finer materials of the drift, if they were ever present, have been carried away, leaving the gravel and boulders.

[46] Leonard, A. G., The pre-Wisconsin drift of North Dakota: Jour. Geology, vol. 24, p. 529, 1916.

[47] Leonard, A. G., Pleistocene drainage changes in western North Dakota: Geol. Soc. America Bull., vol. 27, pp. 296–299, 1916.

In 1916 the present writer examined the boulder bed at the foot of the bluff east of Tobacco Garden Creek and also a ravine cut in unmodified glacial till to a depth of 20 feet below the flat bottom of the creek, in sec. 2, T. 53 N., R. 96 W.

A. J. Collier [48] reports that in 1917 he and Doctor Leonard found an exposure of 60 feet of dense pebbly clay till overlying the sloping eroded surface of the Fort Union shale and sandstone in the lower bluff near Fortner's ranch, in sec. 34, T. 153 N., R. 100 W., on the east side of the Missouri River about 10 miles below Williston, N. Dak., and 3 miles east of Baker's Ferry. So close was the lower part of the till to the water's edge that the face of the till had been gouged by floating river ice. Collier also found 10 feet of till exposed at the water's edge on the west side of the river in sec. 20, T. 153 N., R. 100 W., about 1½ miles above Baker's Ferry. The till is overlain by 7 feet of cross-bedded sand and gravel, and this in turn by 10 feet of alluvium covering the terrace.

From these occurrences and those cited above (p. 75) it appears unquestionable that the Missouri River had occupied its present course through North Dakota and had cut its gorge to at least the present depth, and probably to depths 100 feet or more below its present level, before the advance of the ice sheet which deposited the drift south and west of its channel. In this sense the gorge is preglacial. Whether or not it is of pre-Pleistocene age—that is, Tertiary—depends on whether or not the drift is correlated with the earliest stage of glaciation (Nebraskan) or with a much later one. Concerning the age of this drift, Leonard [49] wrote:

> That the drift west of the Missouri River is much older than the Wisconsin drift is evident from the great amount of erosion it has undergone. Over much of the region the finer materials of the till have been swept away, leaving only boulders and gravel. The older drift also differs in color, being considerably darker than the Wisconsin. The pre-Wisconsin drift has been commonly regarded as Kansan, and there is perhaps more reason for referring it to the invasion of the Kansan ice sheet than any of the other early ice invasions.

In a later paper [50] Leonard describes this as "an older drift, which may be referred to provisionally as the Kansan, though it may prove to be younger."

Wilder,[51] who also was familiar with the several drift sheets in Iowa, wrote:

> About Coal Harbor, which is 80 miles north of Bismarck, there are rather positive indications that an older Wisconsin drift occurs, which probably crosses the Missouri here and at points farther north. Unmodified and rather fresh drift is here found in the Missouri Valley only a few feet above present high water. The topography of the upland at Coal Harbor is not more mature than that of the Iowan drift.

According to Leverett,[52]

> In North Dakota the pre-Wisconsin drift in the vicinity of the Missouri River has well-preserved moraines, and the drift forms a veneer on rather steep slopes as well as on hilltops and valley bottoms. The preservation of these morainic features and of the deposits on the hillsides seems to indicate an Illinoian or Iowan age rather than Kansan.

The writer concurred with Leonard in 1911 in regard to the probable Kansan age of the drift west of the Missouri River, as described in the Bismarck folio, after examining the drift there in company with him. Subsequently, however, in 1914–15, a careful study of the Iowan drift in northeastern Iowa was made by the writer and M. M. Leighton,[53] and at that time the Kansan and Nebraskan drifts were also studied in southern Iowa. Studies of these old drift deposits in 1919 in western Iowa and eastern Nebraska have given the writer a still better personal acquaintance with the indications of relative age of the several drift sheets. There are several considerations which lead to the suggestion that this drift west and south of the Missouri River is probably not as old as Kansan, and the examinations made in 1921 tend to support the opinion that this drift is not older than the Illinoian or perhaps not older than the Iowan stage of glaciation. The occurrence of the till in the Missouri River gorge and in the bottom of the broad valley of Tobacco Garden Creek shows that the greater part of the dissection of the region below the general upland level occurred before this drift was deposited. Much, if not all, of this valley deepening clearly occurred subsequent to the development of No. 2 bench along the old Missouri Valley and Yellowstone Valley in Montana, which is regarded by the writer as of early Pleistocene age. The amount of this erosion accomplished in North Dakota is, considering its location, commensurate with though not equal in depth to that which occurred in the Glacier Park region after the deposition of the oldest drift glaciers of the mountains on the high benches bordering the mountain front (p. 31). After the early mountain glaciation the valleys there appear to have been deepened 1,000 feet or more before the later glaciers extended from the gorges onto the bordering plains. This amount of erosion certainly took considerable time in the Pleistocene. When the plains bordering the Missouri were first glaciated, slopes and uplands were mantled with drift, but the major valleys were probably only partly filled, and there has been no very great amount of erosion since. This is a reason for thinking that the drift on the plains is not very old. If the outer drift in North Dakota is not older than Iowan or Illinoian,

[48] Personal communication.

[49] Leonard, A. G., Jour. Geology, vol. 24, p. 532, 1916.

[50] Leonard, A. G., The geology of North Dakota: Jour. Geology, vol. 27, p. 22, 1919.

[51] Wilder, F. A., North Dakota Geol. Survey Third Bienn. Rept., p. 4, 1904.

[52] Leverett, Frank, Glacial formations in the western United States (abstract): Geol. Soc. America Bull., vol. 28, p. 144, 1917.

[53] Alden, W. C., and Leighton, M. M., The Iowan drift, a review of the evidences of the Iowan stage of glaciation: Iowa Geol. Survey, vol. 26, pp. 49–212, 1917.

there seems no reason for regarding the river gorge as pre-Pleistocene.

It has been shown by Leonard [54] that the Little Missouri River formerly flowed northward through the broad valley of Cherry Creek near Watford City and thence through a sag to and along the valley of Tobacco Garden Creek. The Little Missouri was blocked by the advancing ice sheet and adopted the present eastward-trending course in McKenzie and Dunn Counties when the ice melted away. Along this course it has cut a narrow sinuous gorge in the soft shale and sandstone. Where crossed by the writer south of Watford City the gorge is 500 feet deep. The bluffs are very abrupt and both they and the bordering upland are dissected by a multitude of short branching coulees with no approach to maturity. Owing to the prevalence and softness of the shale and the proximity and depth of the Missouri River gorge, there has of course been considerable erosion since the deposition of the drift. Over most of the area the drift is thin, and in many places the steeper slopes are bare or carry only scattered boulders. There are, however, smoothly rolling upland tracts which are no more dissected than the Iowan drift plain of northeastern Iowa. This is also true of tracts north of the Missouri River and of tracts west of the lower Yellowstone Valley.

None of the drift of the Keewatin ice examined by the writer on the plains of North Dakota and Montana shows such evidences of long exposure to the weather as the Kansan and Nebraskan drifts of eastern Nebraska and southern and western Iowa. In the latter region most of the soluble constituents, such as calcareous rock flour and pebbles and boulders of limestone, have been dissolved out to depths of several feet, in places as much as 10 or 15 feet from the surface. Much of this material has been redeposited at lower levels as calcareous nodules and fillings of joint cracks. In places even the crystalline pebbles and boulders that were included in the upper part of the till have been decomposed, leaving at the top of the till a dense sticky residual clay with sparse pebbles, the gumbotil of Kay.[55] Where this is developed the color of the weathered upper part of the drift, where seen by the writer in southern Iowa, is generally bleached to ash-gray. In eastern Nebraska it is in many places brick-red. Where the gumbotil has been removed by subsequent erosion in southern Iowa, or where deposition has not proceeded so far, the color of the upper part of the drift is oxidized to rusty brown or brick-red, grading downward through brownish yellow. Oxidized bands 1 inch to several inches wide also border the sides of joint cracks, and in places where the clayey till is gypsiferous joint cracks are filled with plates of selenite crystals. These features, together with the mature erosional topography developed on the Kansan drift, are considered indicative of very long exposure of the Kansan and Nebraskan drifts to atmospheric action prior to their being covered by later drift or by loess, which is regarded as of post-Iowan (largely Peorian) age. Whether or not Kay's interpretation of the origin of the gumbotil is accepted, there is abundant evidence of the relatively great age of the Kansan drift.

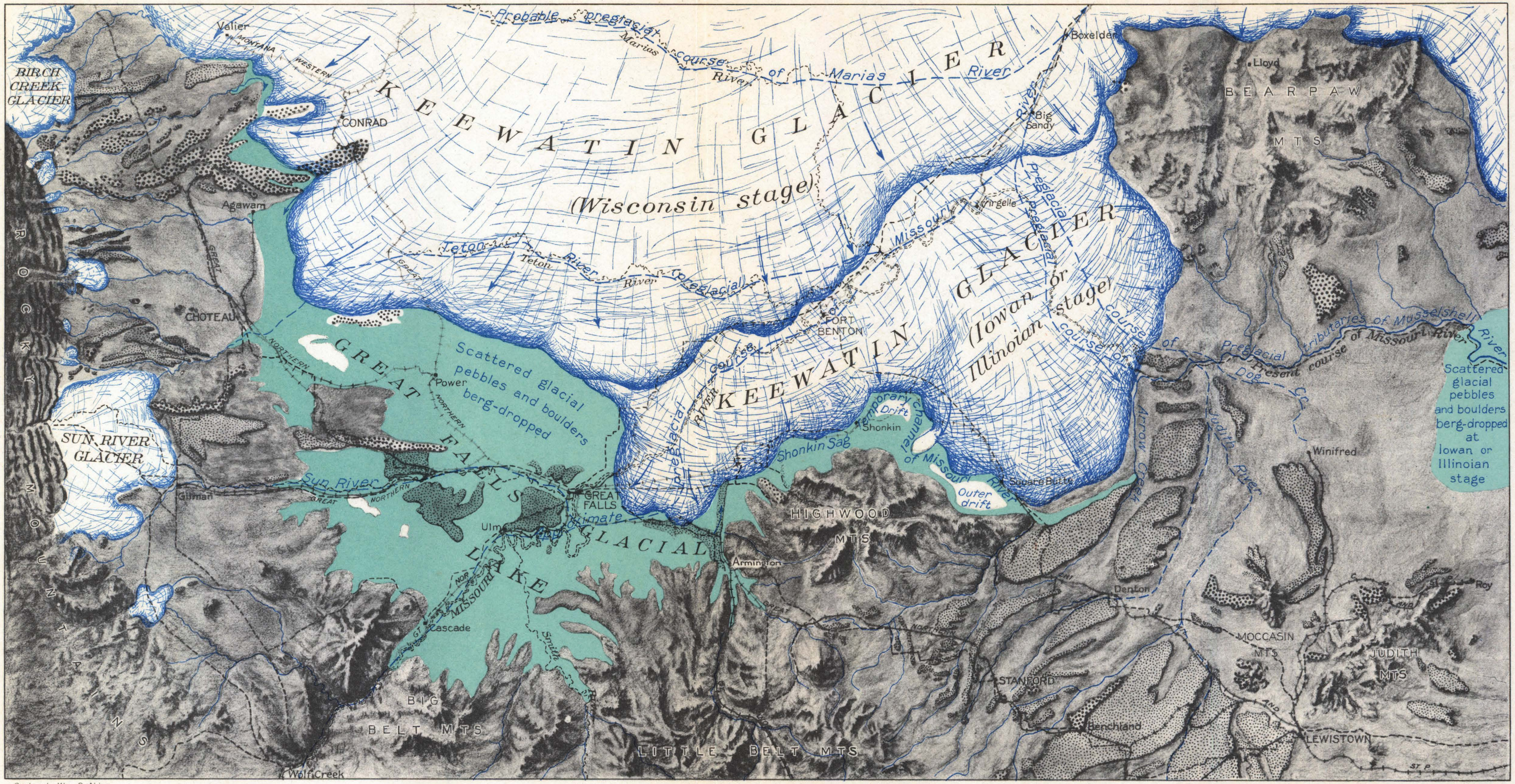
In the parts of North Dakota and Montana under description no such phenomena indicative of great age have been observed by the writer. The till here is not leached of its soluble constituents, and it is not highly colored as the result of oxidation, being generally dark gray to nearly black, like the clay shales from which it is so largely derived. In places, especially where it is somewhat sandy, the upper part of the till has a dull buff tint. Pebbles and boulders of limestone are plentiful clear up to the top of the till and even scattered over its surface. Some of these pebbles within a few feet of the surface still retain their glacial polish and striations. The upper faces of limestone pebbles and boulders lying on the surface of the drift are somewhat roughened and pitted by solution. Their under surfaces as well as those of the quartzite and granitic erratics are generally coated with white calcareous caliche.

Taken as a whole, the phenomena in this region seem to the writer to indicate that this drift is not as old as either the Kansan or the Nebraskan drift of southern Iowa and eastern Nebraska, and that its age is more nearly the same as that of the Iowan drift of northeastern Iowa. Its deposition is therefore tentatively referred to either the Illinoian or the Iowan stage of glaciation. It is recognized that some of the differences between the present condition of this drift and of the Kansan and Nebraskan drifts of the more southerly areas are undoubtedly due to differences in climatic conditions between the two regions and not wholly to difference in age. For example, the mean annual rainfall, which ranges from 20 inches or more in eastern Nebraska to 30 inches or more in southeastern Iowa, declines from 20 inches or more in eastern North Dakota to 15 inches or less in the western part of the State and in eastern Montana. In this semiarid northern region there is now, at least, little downward leaching of soluble salts by percolating water. On the contrary, under the prevailing high rate of evaporation, such salts as are moved are carried upward by capillary action instead of downward and tend to form caliche in the soil or subsoil, or even to coat with caliche the surfaces of pebbles partly covered at the surface of the ground.

Just what climatic differences there were between the two regions in pre-Iowan and post-Kansan time

[54] Leonard, A. G., Pleistocene drainage changes in western North Dakota: Geol. Soc. America Bull., vol. 27, pp. 300–301, 1916.

[55] Kay, G. F., and Pearce, J. N., The origin of gumbotil: Jour. Geology, vol. 28, pp. 89–125, 1920.



Geology by Wm. C. Alden

10 0 10 20 30 Miles

Base 1:500,000 map of Montana, reduced.
Shading by I. M. Pistorio, based on topographic and geologic maps.
Unshaded areas are undulating plains cut in places by sharp gorges and gulches.

EXPLANATION

Rocky Mountain piedmont glaciers and Keewatin ice sheet. (Restored; extent of glaciers west of Rocky Mountain front not shown.)

Marginal glacial lakes and outlets (restored).

Remnants of lower gravelly piedmont terraces of early Pleistocene age.

Remnants of highest gravelly piedmont terraces, probably equivalent of Flaxville gravel, of Miocene or Pliocene age.

MAP OF REGION OF GREAT FALLS, MONT., SHOWING PLAINS AND ADJACENT MOUNTAINS DURING THE PLEISTOCENE OR GLACIAL EPOCH

is unknown. The climatic factors can not be fully evaluated, and no full discussion of them is attempted here.

STREAM DIVERSION AT THE ILLINOIAN OR IOWAN (?) STAGE OF GLACIATION

UPPER MISSOURI RIVER

Calhoun[56] discussed in considerable detail the drainage changes which resulted in the Missouri River abandoning its old valley above the mouth of the Milk River and taking its present course. He did not, however, specifically state whether this change occurred as the result of glaciation at the Wisconsin stage or at an earlier stage. The stream must have been shifted southward temporarily at the earlier (Illinoian or Iowan?) stage of glaciation through practically the whole extent of 700 miles between Sand Coulee, south of Great Falls, Mont., and the mouth of the Cannonball River in North Dakota. East of the mouth of the Milk River, however, after the recession of the earlier ice front the stream finally returned to its earlier course, which was about the same as the present course, except for the cut-off channel between Culbertson and Lakeside, Mont. Between the mouth of the Milk River and Virgelle, however, if the stream reverted to its previous course after the melting of the earlier glacier, it was again shifted south of the Bearpaw and Little Rocky Mountains and the Larb Hills by the Wisconsin ice sheet, and it had become so deeply intrenched along its present channel by the time the early Wisconsin ice front retreated that it never regained its former course, which is now followed in the main by Sandy Creek and the Milk River.

It is evident that the presence of such an ice sheet extending southward across the Missouri River and damming the lower valley of the Yellowstone must have caused very notable changes in drainage. Not only was there much water escaping from the melting ice, but the run-off from all that part of Montana south of the glacial margin and east of the Continental Divide and also the drainage of much of northern Wyoming was blocked and forced to find a temporary outlet eastward through the Glendive quadrangle. Calhoun[57] has shown how the waters ponded in the upper Missouri Valley submerged the whole region about Great Falls beneath the waters of a marginal glacial lake, which he named "Great Falls Lake." (See pl. 29.) This discharged eastward at first through the remarkable channel known as the Shonkin Sag (pl. 30 *A*), which cuts across the present drainage lines and the gently sloping plain just north of the Highwood Mountains. These waters, with those of the Arrow and Judith Rivers and other streams, found their way eastward to the Musselshell by way of tributary channels and across intervening cols along the present course of the Missouri River.

There is a possibility that water ponded in the Musselshell Valley found an outlet for a time southeastward to the Yellowstone near Forsyth, but no abandoned channel has yet been located either there or leading directly eastward from the Musselshell.

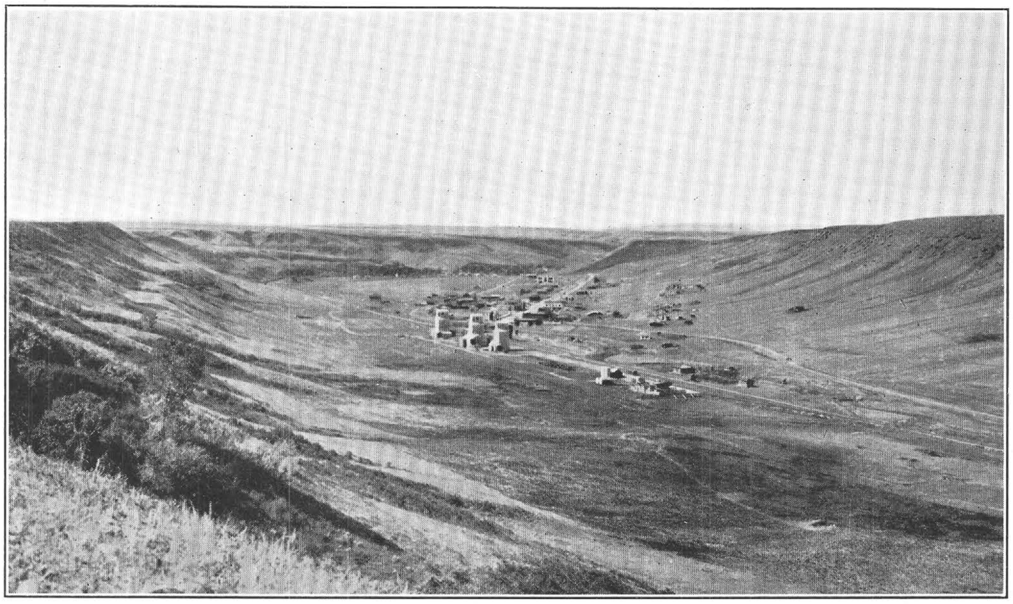
In 1922 Dobbin[58] found what appears to have been the temporary channel by which the waters of the upper Missouri River escaped eastward to the Yellowstone Valley outside the margin of the Illinoian or Iowan (?) ice sheet. This channel trends eastward across northeastern Garfield County and McCone County, mostly through Ts. 21 and 22 N., as shown on Plate 1.

The glacial river entered the Glendive quadrangle near Monrock and crossed the divide through the notch 400 feet deep at Enid, now traversed by the Richey branch of the Great Northern Railway, at about 2,450 feet above sea level. The water at first evidently swung southwestward for about 6 miles from the vicinity of Fox Lake and, passing a second col at about 2,450 feet above sea level, entered the Burns Creek Valley. As the glacial lobe prevented eastward flow along the present course of Dunlap Creek, it turned southward along the ice margin and opened the present anomalous course of Burns Creek to its junction with the South Fork. Thence it continued southward past the east end of the next high bench-topped ridge through a channel, now dry, at about 2,450 feet, to Thirteenmile Creek and the end of the ice lobe. Water must have ponded for about 90 miles in the Yellowstone Valley, nearly as far up as Miles City, for a time at least, for the lowest outlet near the drift limit appears to have been in a general northeasterly direction from the end of the ice lobe at Intake through a series of notches in the divides between Boxelder, Cottonwood, Dry, Smith, Shadwell, and Benny Pierre Creeks, at 2,300 to 2,350 feet above sea level, as shown on the Glendive topographic map. Thence to and beyond the Little Missouri Valley the glacial river followed temporary channels. The presence of blocks of limestone and granite boulders on the edge of the bench north of Custers Lookout and on Belle Prairie, north of Glendive, is probably the result of transportation southward from the glacial front by icebergs floating on the lake held in the valley. Probably the lobe of ice was not competent to hold the vigorous glacial river to its outer channel very long, so that the stream soon cut back the ice or cut a channel across it and went directly eastward down the Fox Creek Valley and

[56] Calhoun, F. H. H., op. cit., pp. 34–45.

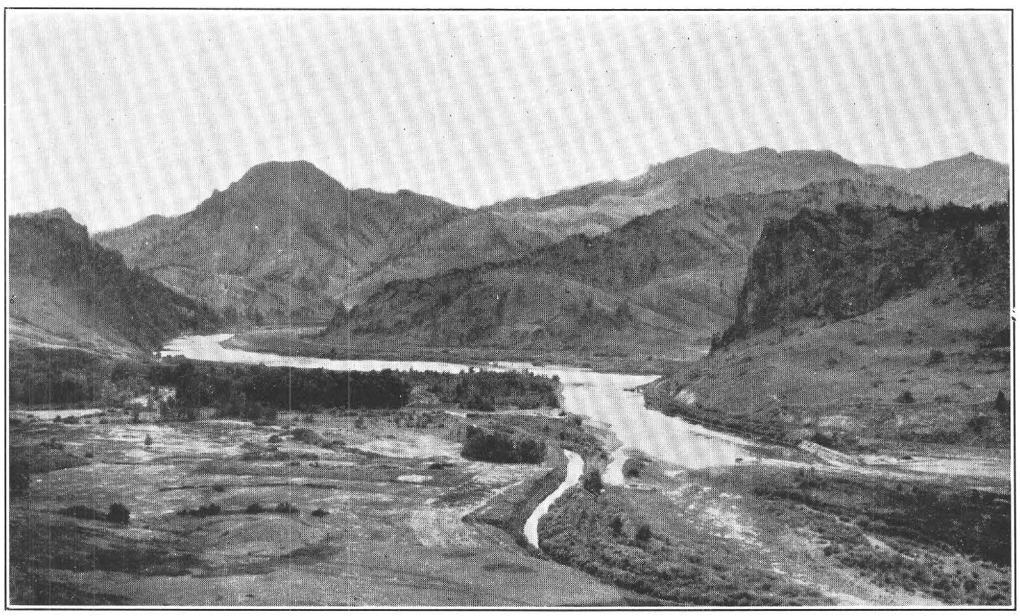
[57] Calhoun, F. H. H., op. cit., pp. 30–31, pl. 5. See also Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), 1899; and Pirsson, L. V., Petrography and geology of the igneous rocks of the Highwood Mountains, Mont.: U. S. Geol. Survey Bull. 237, 1905.

[58] Personal communication.



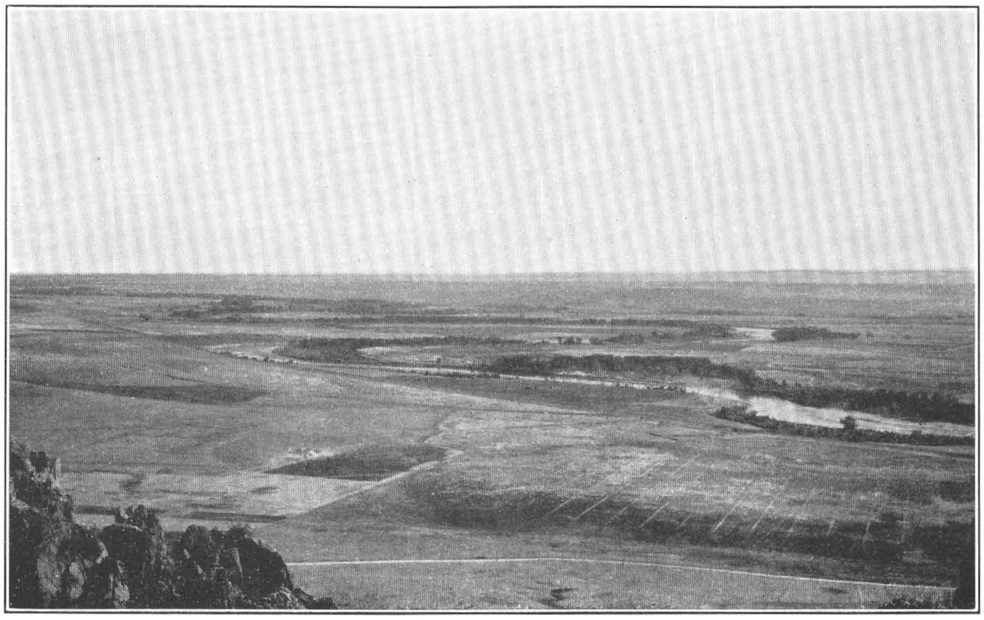
A. SHONKIN SAG NEAR HIGHWOOD

A channel eroded by the Missouri River about the north base of the Highwood Mountains when temporarily diverted by the Keewatin ice sheet, now traversed by the Chicago, Milwaukee, St. Paul & Pacific Railway. This part is 200 to 300 feet deep.



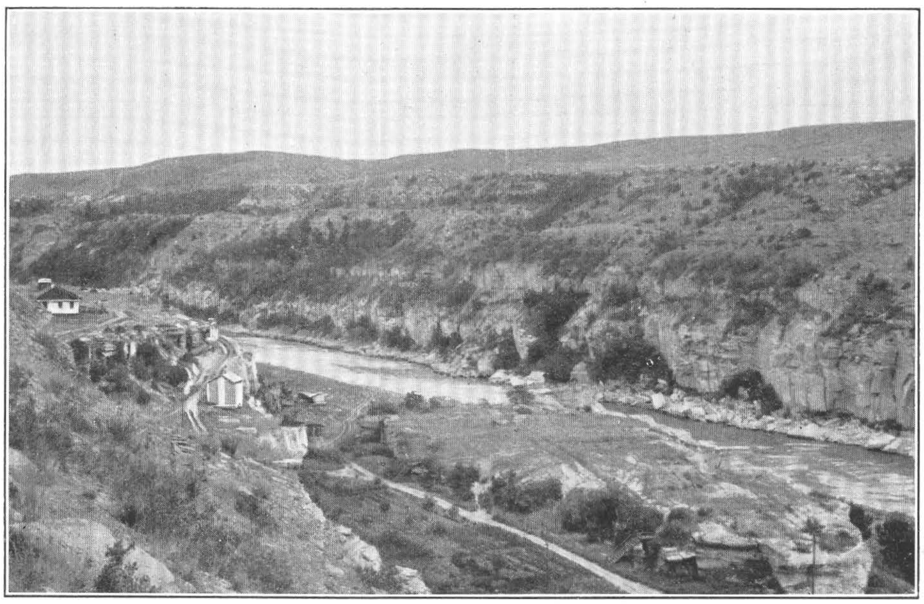
B. MISSOURI RIVER ISSUING FROM THE NORTH END OF THE BELT MOUNTAINS ABOUT 10 MILES ABOVE CASCADE

MISSOURI RIVER, MONT.



A. THE RIVER MEANDERING ON THE PLAIN A FEW MILES BELOW CASCADE

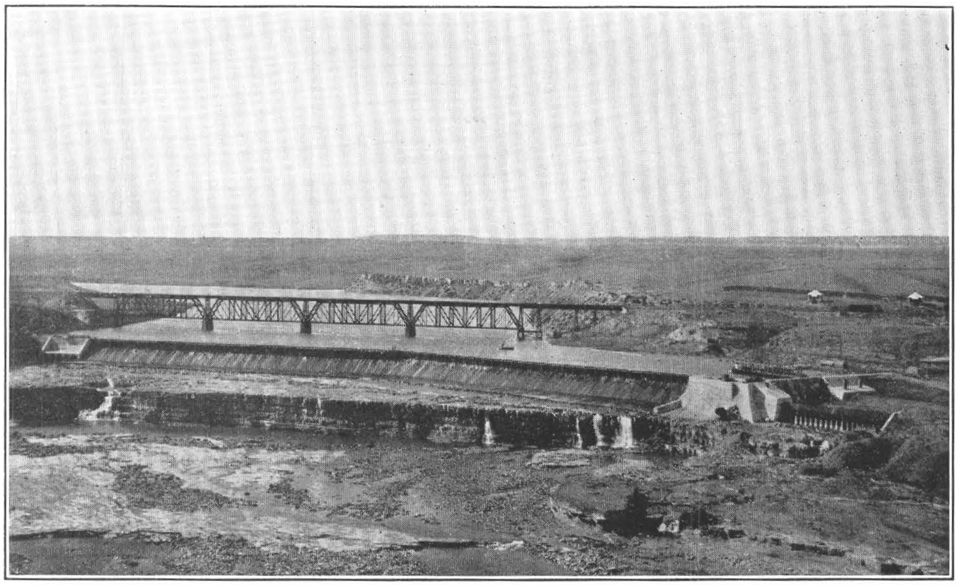
There is probably considerable filling in the preglacial channel beneath the river bed.



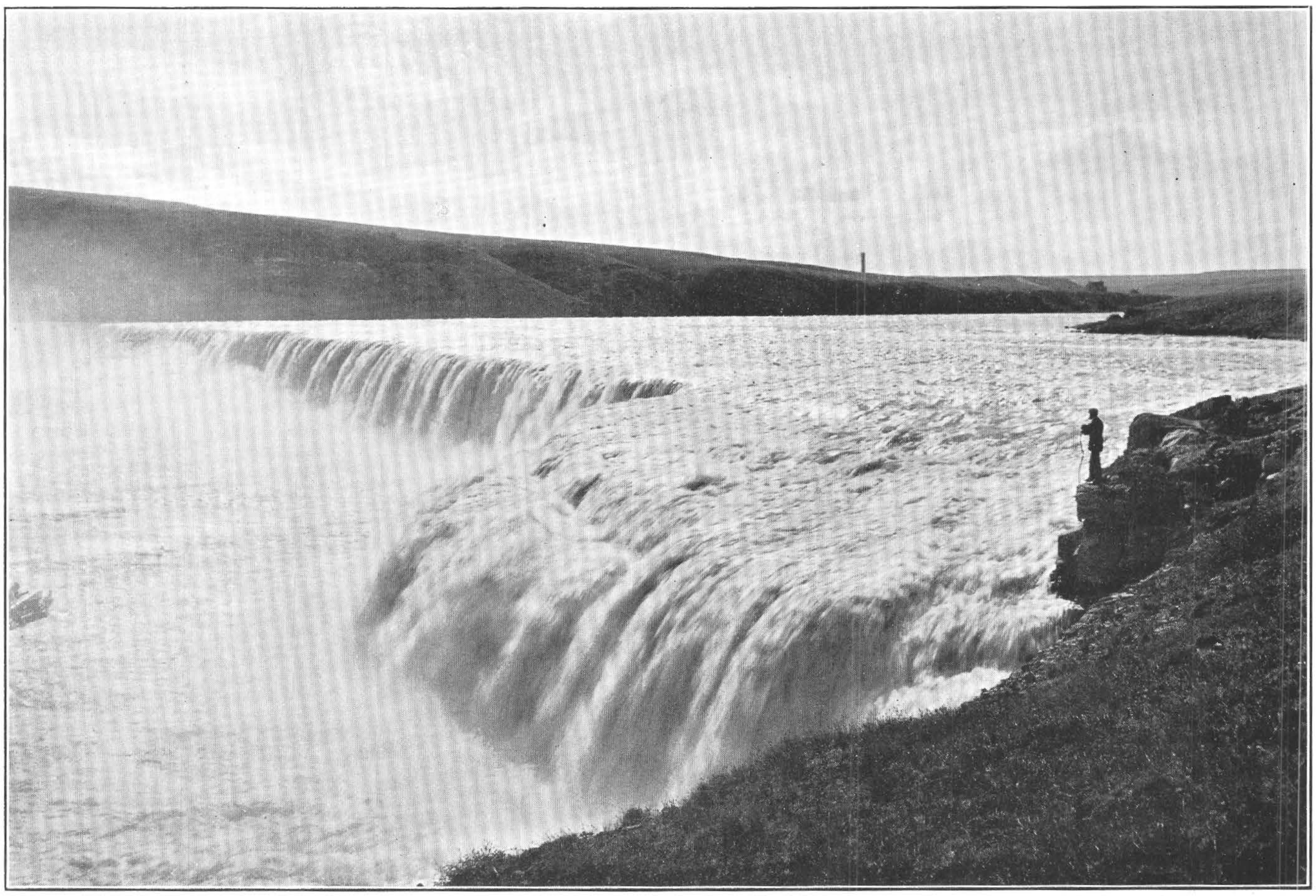
B. POSTGLACIAL (OR POST-IOWAN OR POST-ILLINOIAN) GORGE BELOW BIG FALLS, 10 MILES BELOW GREAT FALLS

Inner gorge about 200 feet deep cut in Cretaceous shale and sandstone below the bottom of a broader valley 200 to 300 feet deep.

MISSOURI RIVER, MONT.



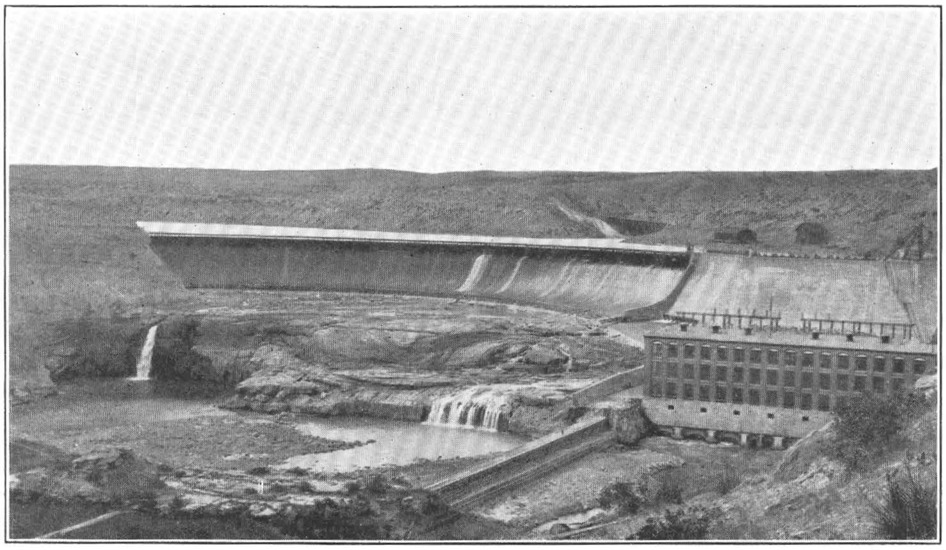
A. RAINBOW FALLS AND DAM OF MONTANA POWER CO., 4 MILES BELOW GREAT FALLS, IN SEPTEMBER, 1920



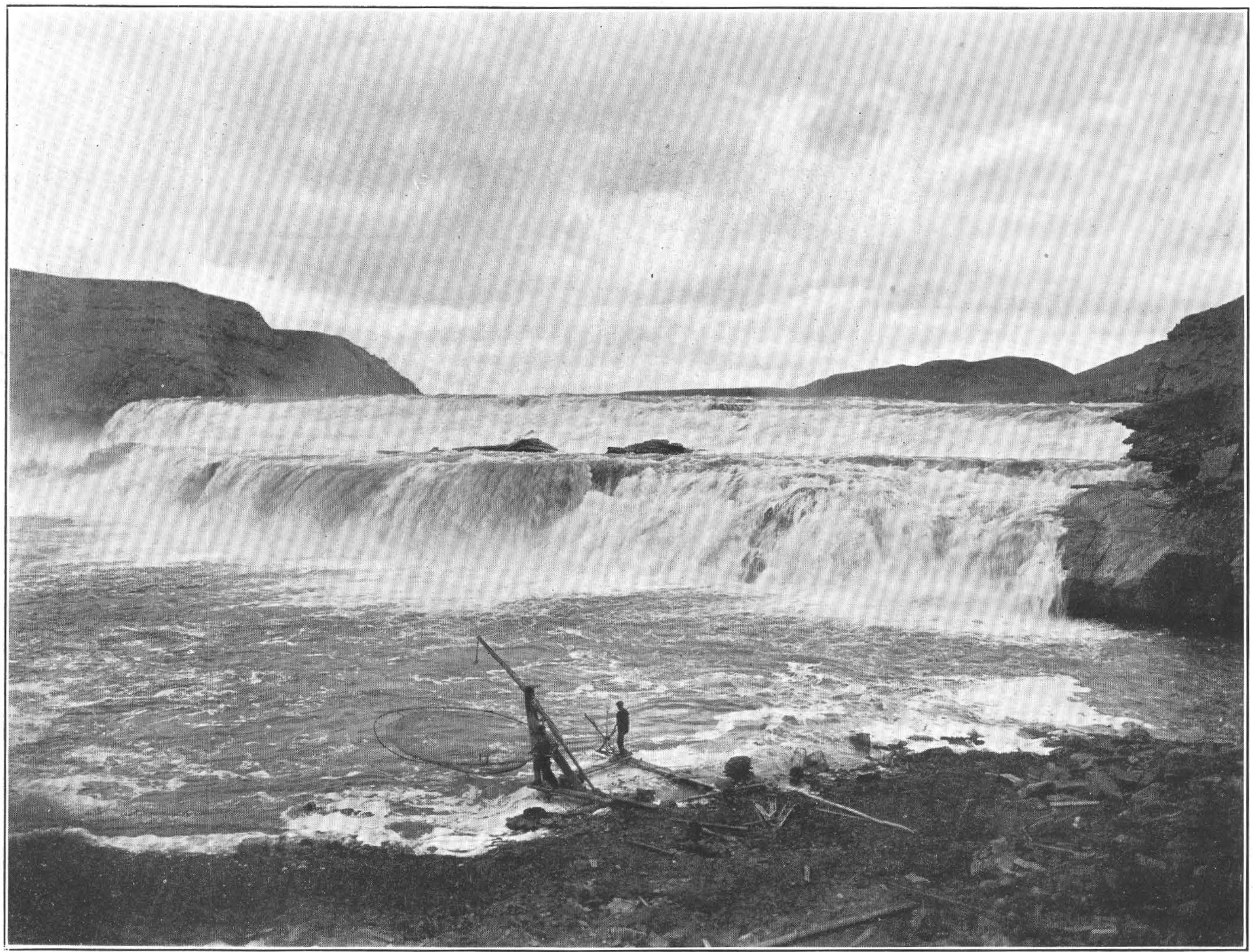
B. RAINBOW FALLS PRIOR TO THE CONSTRUCTION OF THE DAM

Fall 37 feet. Photograph from C. A. Fisher.

MISSOURI RIVER, MONT.



A. BIG FALLS, 10 MILES BELOW GREAT FALLS, AND POWER HOUSE AND DAM OF MONTANA POWER CO. IN SEPTEMBER, 1920



B. BIG FALLS PRIOR TO THE CONSTRUCTION OF THE DAM

Fall 75 feet. Photograph from C. A. Fisher.

MISSOURI RIVER, MONT.

across to and up the valley of Benny Pierre Creek to the gap in the divide noted below.

PLEISTOCENE VALLEY OF THE MISSOURI AND YELLOWSTONE RIVERS

The temporary channels of Missouri River in North Dakota have been described by Leonard [59] as follows:

But while the Missouri River probably occupied its present valley for a considerable time prior to the glacial period [that is, prior to the glacial invasion which in the present paper is tentatively referred to the Illinoian or Iowan stage] the ice sheet, when it invaded the region, blocked the valleys of both the Missouri and Yellowstone Rivers and also the preglacial valley of the Little Missouri, forcing these streams to seek new channels. Lakes were formed in the valleys of the Yellowstone and Little Missouri Rivers, the water rising until it overflowed the divide between the latter and the Knife River south of the Killdeer Mountains. The combined waters of the three rivers flowed east across Dunn County and southeast across Morton to the mouth of the Cannonball River. The valley thus formed crosses the divide between the Knife and Heart Rivers and also that between the Heart and Cannonball. The length of this Pleistocene valley of the Yellowstone and Missouri Rivers from the head of the Knife to the mouth of the Cannonball is 155 miles. It is followed by the Northern Pacific Railroad for 30 miles between Almont and Hebron, this portion of the valley being to-day occupied by Curlew Creek. The Heart River follows the valley for 6 to 8 miles below the mouth of Curlew Creek, and the broad depression continues its southeasterly course through the divide to the Cannonball, being followed for many miles by Louse Creek, a tributary of the Cannonball.

Two broad valleys connect the Knife River Valley with that of Curlew Creek. One enters the latter valley between 3 and 4 miles below Glen Ullin and is followed by the northward-flowing Elm Creek throughout a portion of its extent. Between the latter and the tributary of Curlew Creek the valley bottom is occupied in part by a hay marsh. The other valley, which joins that of Curlew Creek just below Hebron, is known as Farmers Valley and extends to the head of Deep Creek, a tributary of Knife River.

It will be noted that the Knife, Heart, and Cannonball Rivers, together with several of their tributaries, now occupy parts of this old Pleistocene valley of the Missouri and Yellowstone Rivers. The valley is clearly much too large to have been formed by several of the streams which to-day flow through it, such as Curlew, Elm, or Louse Creeks, and some portions now have no streams. Throughout much of its course the old valley has a broad, flat bottom one-half to one mile and more wide, with gently sloping sides.

Quirke [60] discusses the effect on the erosion of the Killdeer Mountains of the diversion of the Little Missouri River to its present west-east course in McKenzie and Dunn Counties. This course, which was assumed as the front of the Illinoian or Iowan (?) ice sheet was melted back from the outermost limit, was much nearer the north flank of the Killdeer Mountains than the former channel past Watford City to and along Tobacco Garden Creek, and as the gorge was rapidly deepened in the soft shale and sandstone the gradients of certain tributaries were greatly increased, and in consequence these streams gained ascendancy over those not so affected.

STREAM CHANGES NEAR GREAT FALLS

In the region of Great Falls the relations of the course the Missouri assumed after the melting of the Illinoian or Iowan (?) ice to the several temporary channels and to the earlier ones now buried in drift are of considerable interest. The present studies have added but little to our knowledge of these relations. Inasmuch as there are but few copies of Calhoun's paper now available, it seems wise to reproduce some of the details which he worked out. The following description (pp. 89–93) is taken with slight modifications from that paper: [61]

The Missouri River rises in the extreme southwestern portion of Montana and flows northeastward. For the first 300 miles it is confined by mountains, but after passing between the main ranges of the Rocky Mountains at the north end of the Belt Mountains it escapes to the plain. (See pl. 30 *B*.) From this place to Great Falls the river meanders over a wide flood plain, flowing 75 miles with a fall of but 85 feet. (See pl. 31 *A*.) At Great Falls an abrupt change in the character of the stream takes place. Leaving the plain, it flows through a canyon with high shale and sandstone walls and falls 612 feet in about 10 miles.[62]

In this part of its course the river runs in a gorge, in which cataracts have developed (pls. 31 *B*, 32, 33) because of the harder ferruginous layers found in the sandstone. The unequal rate at which the falls have retreated is due to the varying hardness of these layers. It is not known exactly at what point the falls originated, but it was doubtless where the superimposed Missouri found its way over the side of an old valley wall, either into its own pre-glacial channel or into that of one of its tributaries. This, so far as now known, may have happened at any one of a number of places. At a point near the mouth of Belt Creek the valley suddenly broadens and at the same time turns abruptly to the north. Here the river flows through an old drift-filled pre-glacial valley. The post-Illinoian or post-Iowan river does not everywhere flow in the old channel but crosses it at all

[59] Leonard, A. G., Pleistocene drainage changes in western North Dakota: Geol Soc. America Bull., vol. 27, p. 299, 1916.

[60] Quirke, T. T., The geology of the Killdeer Mountains, North Dakota: Jour. Geology, vol. 26, pp. 260–263, 1918.

[61] Calhoun, F. H. H., op. cit., pp. 34–43.

[62] Calhoun gives the fall as 512 feet in 12 miles. C. A. Fisher (Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, p. 76, 1909) gives the total fall as 612 feet in approximately 10 miles between the Great Northern Railway bridge at Great Falls and the mouth of Belt Creek.

angles. This unconformity of the old channel to the present one is shown in the sections forming Figure 7.

At the big bend of the Missouri, at the mouth of Little Sandy Creek, there is another abrupt change in the character and direction of the valley. The river, which has been flowing northeastward, turns abruptly to the southeast. The valley narrows and becomes more canyonlike, and the drift disappears. The upland on both sides of the stream slopes to the north, but the river flows south. At the mouth of the Arrow River there is a sudden turn to the east, though the character of the valley does not change. The river continues to flow between high rock walls, with little bottom land, in a valley that narrows and widens without apparent cause. From the mouth of the Musselshell to that of the Milk River the valley is narrow, with walls 600 to 1,000 feet high.

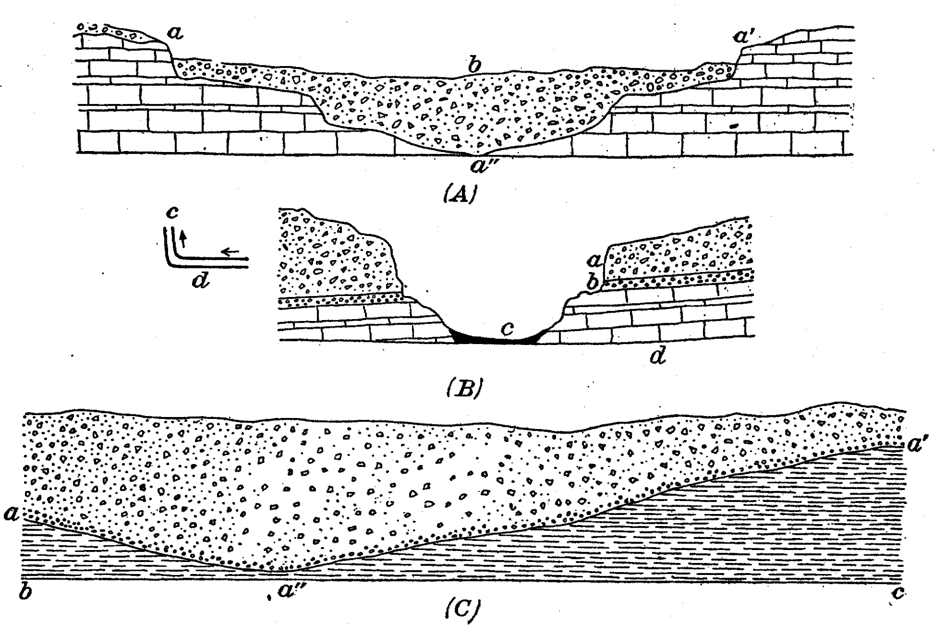


FIGURE 7.—Sections showing the preglacial valley of the Missouri. *A*, Old valley of the Missouri, 12 miles wide; *a* and *a'* represent the exposed sandstone bluffs of the preglacial valley; *b* is the drift filling. *B*, Section across the postglacial gorge (*c*), which is cut through glacial drift (*a*) and through the sloping older gravelly bed of the river (*b*) and into sandstone. *C*, Section exposed in side of the postglacial gorge above the present stream bed (*b a'' c*) showing the older valley (*a a'' a'*) filled with glacial drift. (From F. H. H. Calhoun)

It is evident that the river near Great Falls is not in its old valley. Between the meandering stream west of the town and the river in its great drift-filled valley east of the mouth of Highwood Creek extends a canyonlike valley with a series of rapids and falls. Well borings along the river southwest of the town show that the stream is now flowing on a flood plain about 270 feet above the bottom of the preglacial valley. A well at Ulm, drilled by the Great Northern Railway Co. about 1888, went down some 270 feet through sand and clay into a gravel layer.[63]

A well on the Odell ranch, on the Missouri south of Great Falls, went through the following material:

Record of well on Missouri River south of Great Falls, Mont.

	Feet		Feet
Soil	20	Gravel	7
Quicksand	125		
Clay	60		212

These two well sections show conclusively that the valley of the Missouri was formerly much deeper and that it has been filled with deposits.

The reasons for thinking that Sand Coulee Creek now occupies the old channel of the Missouri are as follows: (1) The topographic relations are such that a broad valley like that now occupied by Sand Coulee Creek could not have been formed by that stream or by any stream flowing westward; (2) the cross section of Sand Coulee Valley, though not quite as large as that of the Missouri, is of the same general shape; (3) Sand Coulee Valley contains great meanders, and if the Missouri could be turned into it the resemblance to the Missouri from Ulm to the junction of Sand Coulee would be striking; (4) the tributary valleys which now join Sand Coulee Valley have their acute angles on the donwstream side and therefore appear to have been formed when the water in the valley flowed in the other direction; (5) at the lower end of Sand Coulee Valley there is a deposit of lacustrine clay, and at the upper end a deposit of boulder clay, which appears to block the old channel at this point.

East of Gibson's ranch Sand Coulee runs into a broad plain, the southern edge of which marks the limit of the drift. Here the old valley has been filled by a drift dam to such a height that the water ponded in front of the moraine found its outlet to the north over Cretaceous sandstone. (See fig. 8.) The waters of the diverted stream entered the old valley near the mouth of Highwood Creek, and it was doubtless at this point that the falls originated. (See fig. 9.) Figure 10 gives some idea of how the new channel cut across the meanders of the old.

At the mouth of Little Sandy Creek, east of Virgelle, the abrupt turn to the south, the narrow rock-walled valley, and the wide drift-filled valley stretching off northeastward to the Milk River all suggest that the river has again been diverted. The latter

[63] This information was given by P. W. Bradford, of Great Falls. No record was kept of the depth and of the material by the railway company, but his figures agree essentially with those of Mr. Chaffie, a well digger of Great Falls, who has sunk other wells in the vicinity.

valley is 35 miles long and is occupied by two streams —Sandy Creek, flowing north into the Milk River, and Little Sandy Creek, flowing into the Missouri. (See fig. 11.)

The thickness of the drift deposit in the Sandy Creek Valley north of the Missouri could not be determined. Little Sandy Creek has cut a channel 60 feet into the drift without reaching rock. From this point to Havre there is no cut of more than 20 feet.

This valley joins that of the Milk River east of Havre. South of Havre there is a drift filling 140 feet thick. Plate 34 shows the relations of the present streams to the old valley.

The valley of the Milk River above its junction with the preglacial valley of the Missouri ranges in width from a quarter to half a mile, but below the junction it is 2 to 3 miles wide. Southward from the turn at the mouth of Little Sandy Creek the Missouri flows between high rock walls. The bottoms are few and small and the current rapid. The Arrow, Judith, and Musselshell Rivers and Dog Creek are tributaries in this part of its course, and each one has been affected by the change in the direction of the trunk stream.

In order to illustrate the conditions under which these changes took place and the reason for each change Figures 12, 13, 14, and 15 have been prepared. Figure 12 illustrates the preglacial drainage system, Figure 15 the post-Illinoian or post-Iowan system, and Figures 13 and 14 intermediate stages. Figure 12 is more or less ideal, for, owing to the weathering of the soft sandstone, valley contours have been greatly modified by the drift, making difficult the work of restoring the minor drainage lines.

The major changes in drainage caused by the Illinoian or Iowan (?) ice sheet appear to be closely connected with the history of the Shonkin Sag, a valley which runs from Highwood Creek to the Arrow River. (See pls. 29 and 30 *A*.) The sag is in places nearly a mile wide and over 500 feet deep. It is entirely independent of rock structure and runs across the present drainage lines at right angles. Another curious feature of its position is that it is superimposed on the sloping upland bordering the northern foot of the Highwood Mountains. It would be impossible for a river in the normal course of development to erode such a channel. At the time of the maximum extent of the ice sheet Great Falls Lake drained eastward.

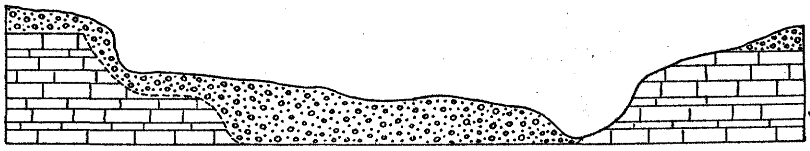


FIGURE 8.—Cross section showing the drift in the valley through which Highwood Creek now flows. Looking north, downstream. (From F. H. H. Calhoun)

The west end of the Shonkin Sag must have been covered by the ice edge, because the waters touched the 3,900-foot contour level. At this level a wide, shallow valley extends 200 or more feet above Belt and Highwood Creeks and runs at right angles to them. Though most plainly marked between these two streams, the same valley is found at intervals along the south bank of the sag, in places with two banks, in places with only one, the north wall having been formed by the ice itself.

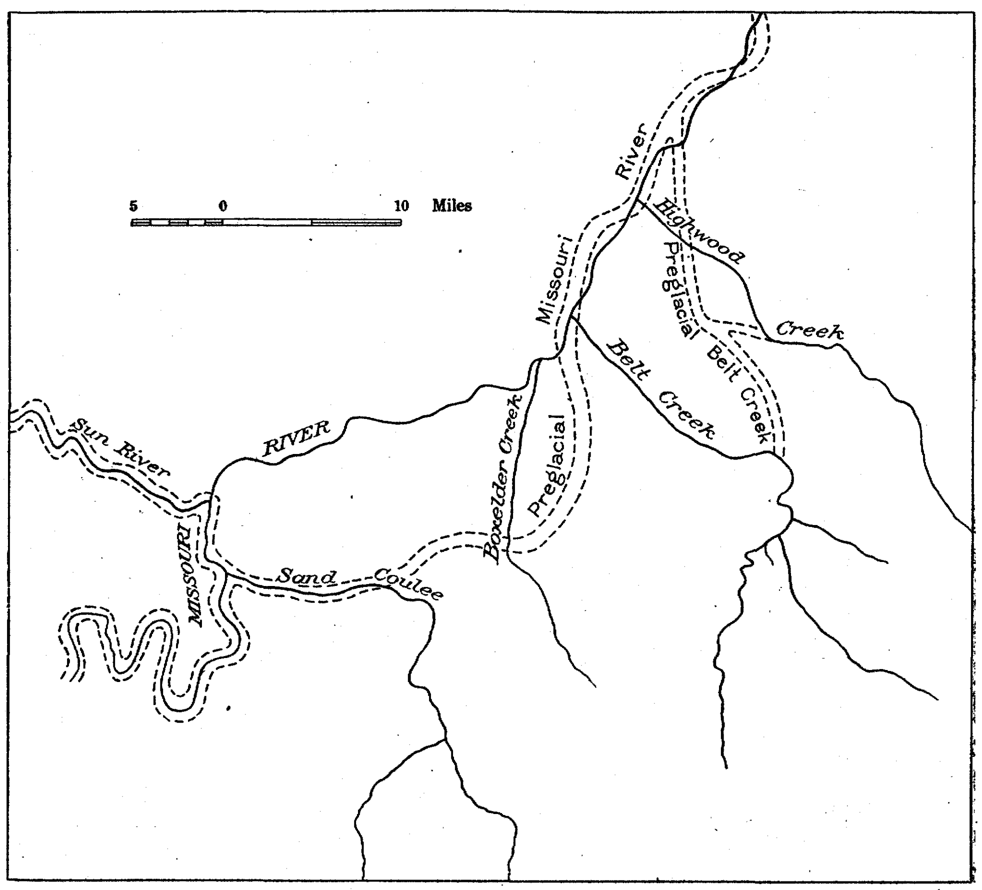


FIGURE 9.—Map showing the preglacial course of the Missouri River between Sand Coulee and the mouth of Highwood Creek. (From F. H. H. Calhoun)

The valley is such as would be formed by a great quantity of water flowing for a short time from a lake. After this valley had been cut and the floating ice had

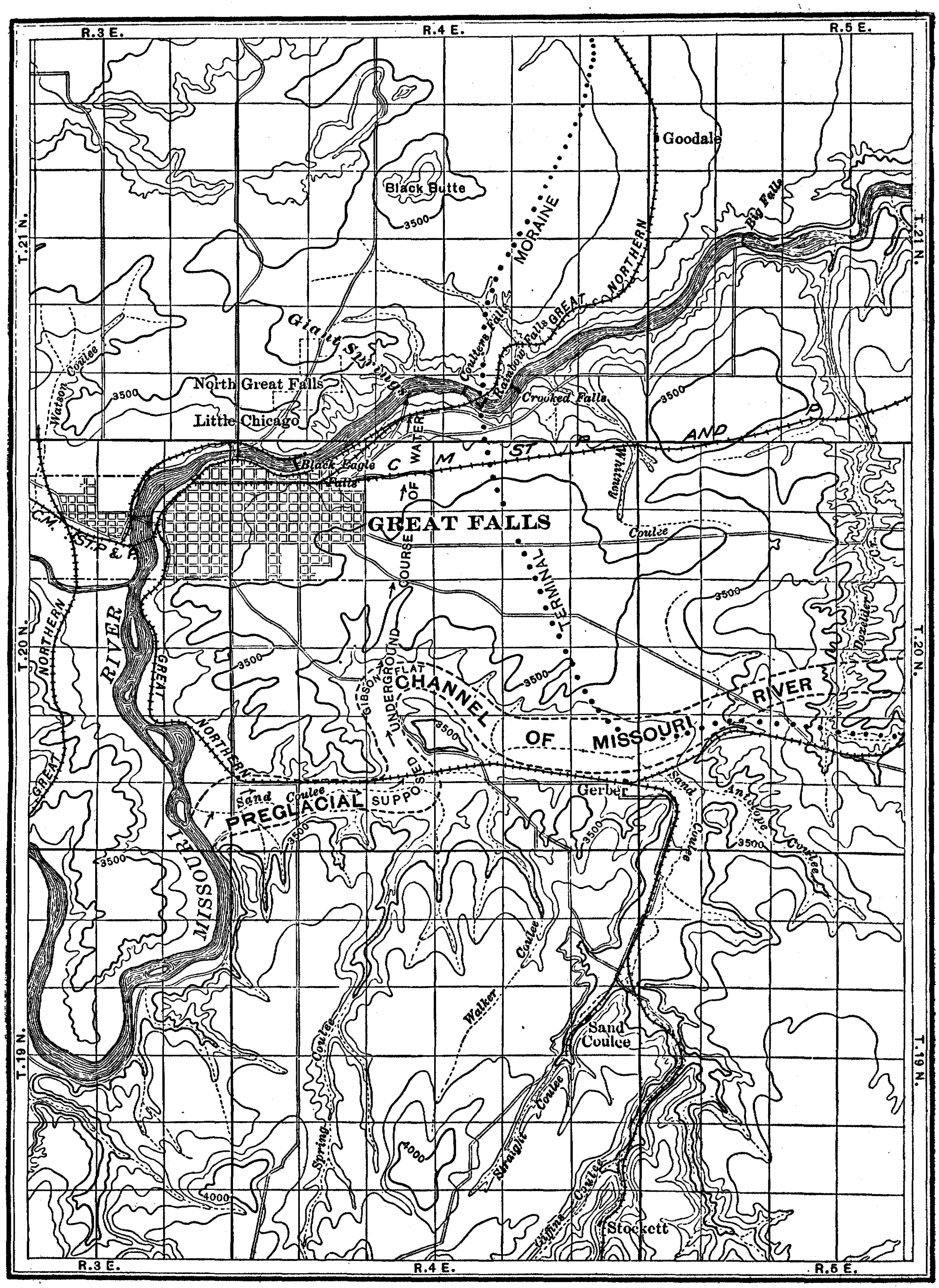


Figure 10.—Map of the vicinity of Great Falls, Mont., showing location of the partly buried preglacial channel of Missouri River. Contour interval 100 feet. (Modified from C. A. Fisher)

carried the boulders over the region covered by Great Falls Lake, the ice front was melted back to the north bank of the sag and allowed the waters to flow at a lower level. The method of formation of the sag seems to have been as follows: The drainage of the lake was forced by the position of the ice edge across the streams flowing from the Highwood Mountains. The waters took advantage of each col and tributary and swung in great meanders around the mountains. The sag appears to be the result of superimposing across the preglacial valleys a drainage system determined partly by topography and partly by the position of the ice edge. The manner in which this change was brought about is illustrated in Plate 29. The sag continued to be the outlet for the waters of the lake until the ice front had retreated north of Fort Benton.

It is not known whether or not the Missouri River returned to its former course west and north of the Bearpaw Mountains after the front of the Illinoian or Iowan (?) ice retreated. If it did it was again diverted south of the Bearpaw Mountains when the ice readvanced at the early Wisconsin stage. In North Dakota and eastern Montana, east of the present mouth of the Milk River, the Missouri River returned to its former course, and it has continued flowing there since. It is not known that the Keewatin ice obstructed the present course of the Missouri at the Wisconsin stage anywhere in this region. In its lower course the Little Missouri adopted the present eastward-trending channel and never returned to the Tobacco Garden Valley.

PEORIAN (?) STAGE OF DEGLACIATION

It is not certain that renewed uplift immediately preceded the invasion of the Wisconsin glaciers. In the Mississippi Valley conditions favorable to dust storms seem to have prevailed for some time immediately after the melting of the Iowan ice sheet and to have resulted in the formation of a notable deposit of loess. Loess or loesslike material overlies the older Keewatin drift and underlies the Wisconsin till at one of the exposures examined by Calhoun on the St. Mary River (fig. 3) and at one of the exposures seen by the writer near Lethbridge, Alberta. This may or may not be significant. In the section observed by Calhoun there is 10 feet of black clayey loam in the midst of the loess, underlain by 5 feet of loess and overlain by 6 feet of loess, above which is Wisconsin till. Possibly this black loam represents the soil at the top of the Sangamon loess in Iowa and Illinois.

The relations of certain wind-blown silts exposed in the railway cut west of Fort Benton are shown on page 66. The sandy clay (No. 4) of that section is, in places, crumpled into small folds overturned toward the southeast as if pushed by an overriding glacier. (See pl. 1.)

During the Peorian (?) interval a moderate amount of erosion of the Illinoian or Iowan drift (?) was probably accomplished, but the upper part of the drift was in this region modified very little as the result of leaching and oxidation. The pre-Wisconsin till observed by Stebinger on Sage Creek (p. 74) is considerably weathered. There is only 6 feet of the till, and it contains very few limestone pebbles, most of them probably having been removed by solution, as such pebbles are fairly abundant in the overlying

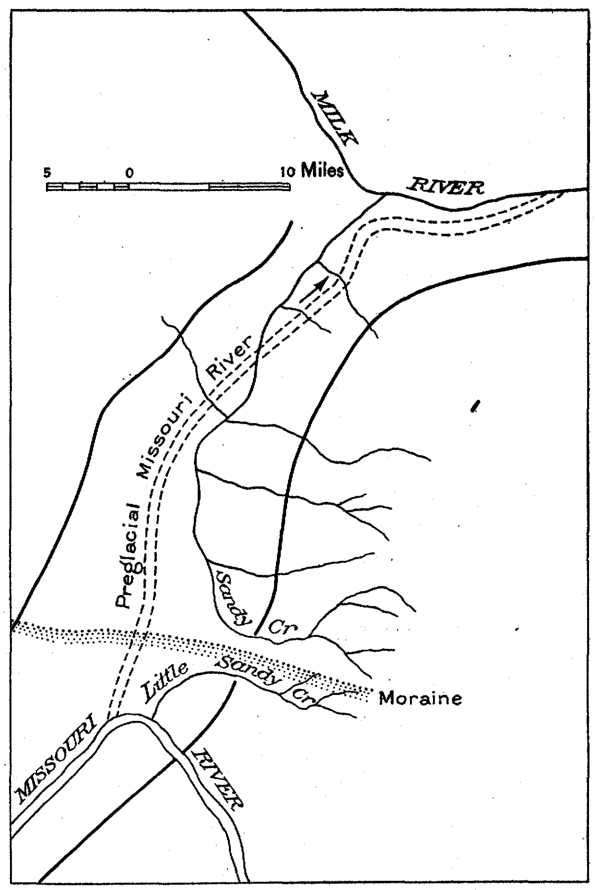


FIGURE 11.—Map showing the preglacial valley between the Missouri and Milk Rivers. (Redrawn from F. H. H. Calhoun. Space between heavy lines shows width of the old valley)

Wisconsin till. Included crystalline pebbles from Canada are much decayed and friable. The till is partly indurated in places and deeply iron stained.

In the exposures of the older Keewatin drift seen by the writer on the Belly and Old Man Rivers in Alberta less modification due to pre-Wisconsin weathering was observed

WISCONSIN STAGE OF GLACIATION

AGE OF THE DRIFT

Considerable diversity of opinion concerning the age of the drift in Montana and western North Dakota has been expressed on maps in published papers. This apparently is due in part to indefiniteness of the evidence and in part to lack of adequate field observations, and it must be admitted that the present investigation has not done very much toward stabilizing these opinions. The outer great moraine of the later Wisconsin drift is fairly well defined on the Coteau du Missouri in northwestern North Dakota, so that its delineation on the maps has varied but little. It is shown by Chamberlin [64] as extending northwestward between the Mouse [Souris] and Missouri Rivers to the northwest corner of what was then Dakota Territory. The age of the drift outside this moraine is not indicated, but its approximate limit as drawn is not greatly different from that on Leonard's maps in North Dakota. Chamberlin's map covers but little of the area west of the lower Yellowstone. The map accompanying a later paper by Chamberlin [65] shows the same extent of later drift and labels all the drift outside this limit on the plains of the Dakotas and Montana as "earlier drift."

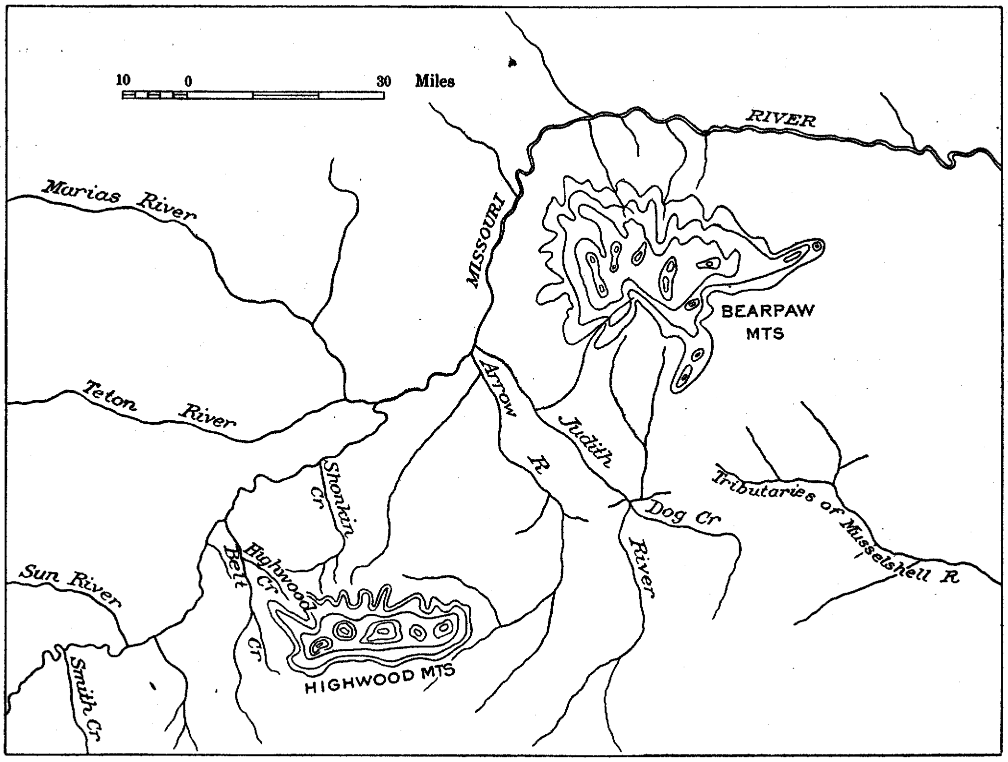


FIGURE 12.—Map showing preglacial river system of northern Montana. (After F. H. H. Calhoun)

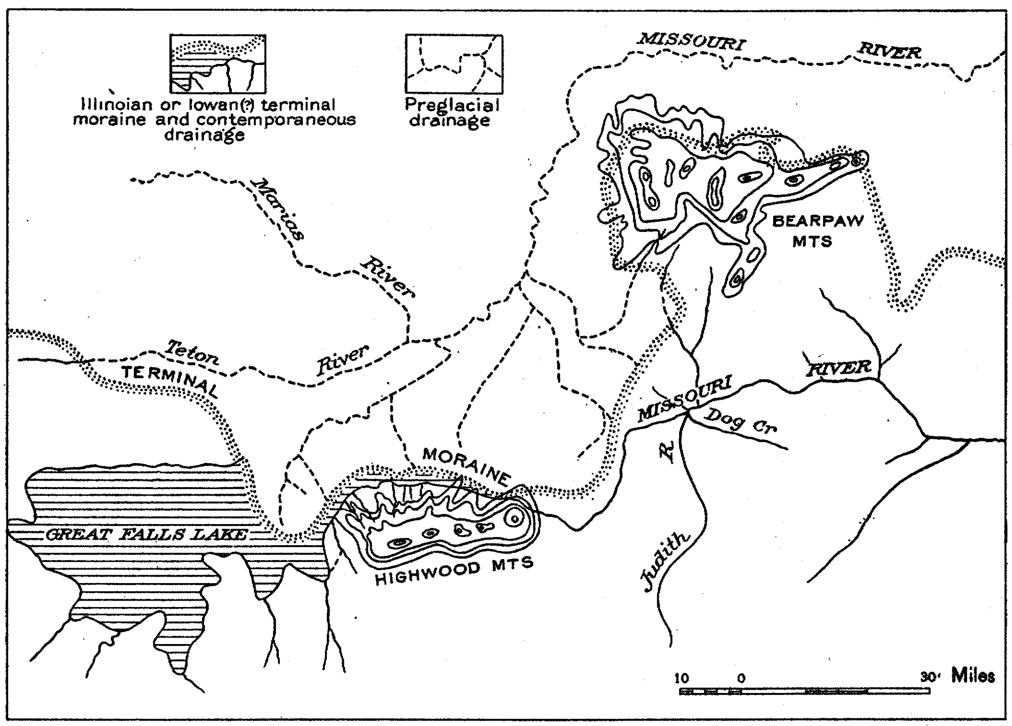


FIGURE 13.—Map showing drainage of part of northern Montana when the Illinoian or Iowan (?) ice had maximum extent, and also preglacial river system. (After F. H. H. Calhoun)

On Upham's map of the glaciated area of North America [66] the boundary of the later drift (or "East Wisconsin stage") was drawn westward through what was then southern Assiniboia (now Saskatchewan) to the southeast corner of Alberta, and the drift along and south of the international boundary was referred to the "early Kansan and east Iowan stages of glaciation," undifferentiated.

In 1899 this supposed "older drift" in southern Assiniboia and Montana outside the limit of what was then designated Wisconsin drift was shown by Leverett [67] as Kansan.

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[64] Chamberlin, T. C., Terminal moraine of the second glacial epoch: U. S. Geol. Survey Third Ann. Rept., pl. 35, 1883.

[65] Chamberlin, T. C., Rock scorings of the great ice invasions: U. S. Geol. Survey Seventh Ann. Rept., pl. 8, 1888.

[66] Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, pl. 16, 1895.

[67] Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Mon. 38, pl. 1, 1899.

In 1906 was published Calhoun's paper [68] giving the results of several seasons' study of the drift of the continental ice sheets in Montana and of the Rocky Mountain glaciers. Calhoun concluded that most of the drift north of the Missouri River in Montana was of Wisconsin age, and his map shows the extent of Wisconsin drift approximately the same as that on Plate 1 of the present paper as far east as the east side of the Little Rocky Mountains. The drift south of this margin was shown as "older drift." He states [69]: "The fact that there is such a border of drift without the terminal moraine suggests two different ice epochs, but very little was found in the field to support this theory." His investigations did not extend as far east as North Dakota.

As shown by Calhoun [70] and by Stebinger and the writer,[71] there can be little doubt that the drift of the Keewatin ice sheet in the Blackfeet Indian Reservation and thence south to the moraine north of the Missouri River between Great Falls and the Bearpaw Mountains is of Wisconsin age. Calhoun traced the margin of this drift eastward along the north side of the Bearpaw and Little Rocky Mountains, but farther east no moraine was definitely mapped. What has been regarded as the outer moraine of the Wisconsin drift in North Dakota is the so-called Altamont moraine, a broad, strongly marked morainal belt which extends northwestward along the Coteau du Missouri into the northeast corner of Montana, in Sheridan County. In 1916 the writer made a series of traverses from north to south across that part of Montana lying between the Missouri River and the Canadian boundary and northward 40 to 50 miles into southern Sas-

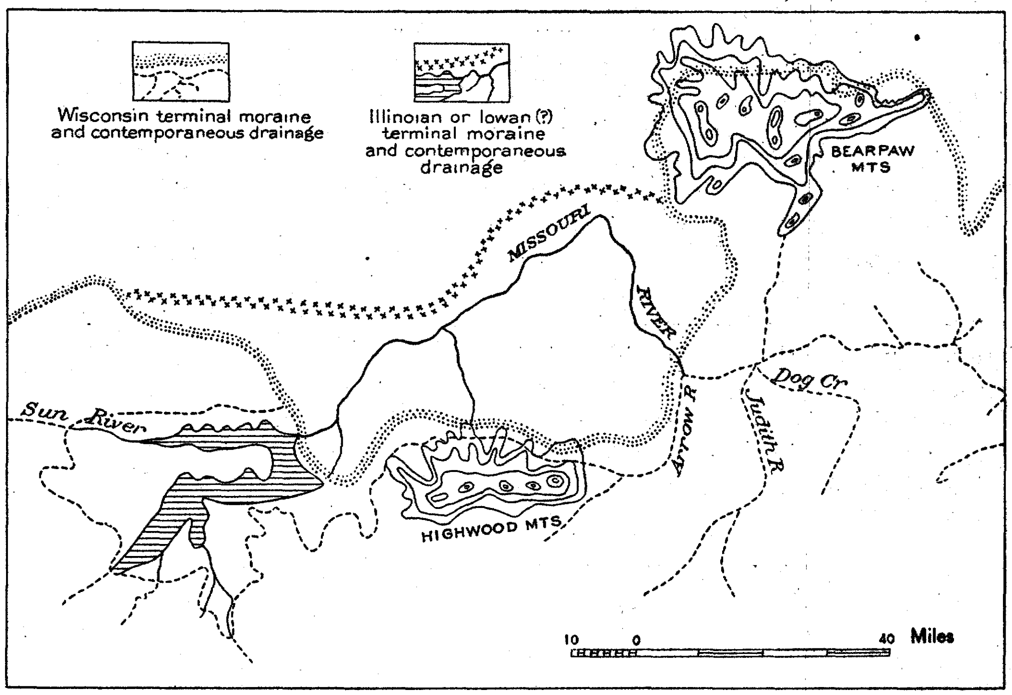


Figure 14.—Map showing drainage of part of northern Montana at early Wisconsin stage. (After F. H. H. Calhoun)

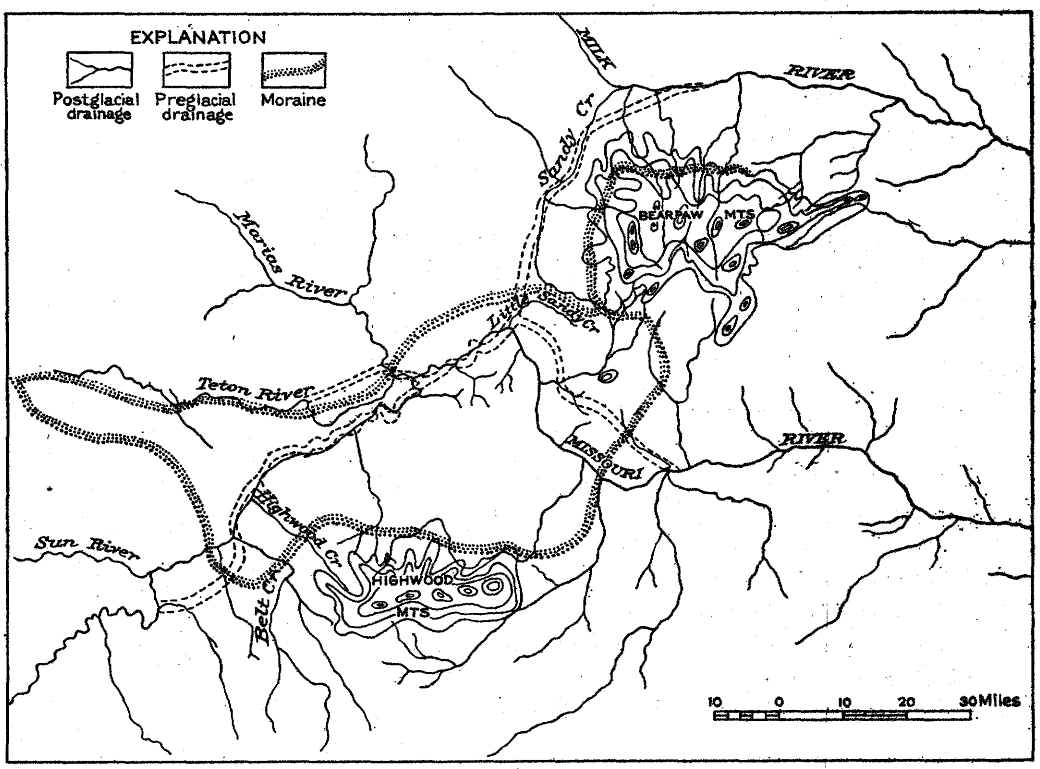


FIGURE 15.—Map showing postglacial drainage system of part of northern Montana, with a part of the preglacial system. (After F. H. H. Calhoun)

[68] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.

[69] Idem, p. 55.

[70] Idem, pp. 52–54.

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

katchewan in the expectation that this moraine would be found extending around the higher part of the Wood Mountain upland and thence southward or southwestward again into Montana to the region of the Little Rocky and Bearpaw Mountains. Other traverses were made in 1920, but no evidence of such southwesterly trend of the Altamont moraine was found. The writer has therefore been forced to the conclusion that the limit of the later Wisconsin glaciation marked by the Altamont moraine as described below (pp. 126–129) probably continues northwestward from the northeast corner of Montana and that the Keewatin ice, which formed the moraines near the mountains, was that of an earlier Wisconsin substage. Careful study of the topographic relations of such morainal deposits indicates that the limit of the early Wisconsin drift is very indefinite but probably lies along approximately the sinuous line traced on Plate 1. The character and relations of these deposits are described below.

EARLY WISCONSIN GLACIATION

GENERAL RELATIONS

The conditions outlined above seem to the writer to indicate that earlier Wisconsin drift emerges from beneath the later Wisconsin in northwestern North Dakota and extends thence westward to the limits of the "later drift" north of the Missouri River in Montana, approximately as mapped by Calhoun. This is in harmony with conditions in northeastern Minnesota, Wisconsin, and Illinois, where Leverett[72] has mapped Wisconsin drift extending in places far beyond the limits of later readvances of the Wisconsin ice sheet.

Traces of a terminal moraine east of the Little Rocky Mountains are scant and discontinuous and so may be described somewhat in detail. Further field examinations are necessary before their correlation can be considered satisfactory.

EARLY WISCONSIN TERMINAL MORAINE (?) IN NORTH DAKOTA

Willard and Erickson,[73] on a map of a part of northwestern North Dakota, showed the deposits of the Altamont moraine extending southwestward along the divide between the valley of Shell Creek and that of the Little Knife River and also extending across the line of the Great Northern Railway in the area south of Ross and west of the Little Knife Valley. In the accompanying description[74] they state that "Long lobes pushed out from the front of the ice also, and thus the outer edge of the great deposit from the ice, which is known as the moraine, is very irregular and uneven." There is some reason for thinking that these deposits, instead of representing lobes of the Altamont moraine, belong with a somewhat earlier moraine which is here emerging from beneath the late Wisconsin deposits.

Leonard[75] refers to the occurrence of morainal deposits near the White Earth Valley, in western Mountrail County, and near Temple, in eastern Williams County. The deposits near Temple are contoured on the Ray topographic map. This belt was crossed in 1916 by the writer in company with Dr. Leonard on a trip from the Missouri River north to the Great Northern Railway at White Earth, and a well-marked moraine belt was traversed most of the way eastward to Stanley, on the south side of the railroad.

Wood[76] states that

> the lakes at the head of the Shell Creek are a part of the headwaters of the stream which have been obstructed and cut off from the valley by the accumulation of drift. The lakes near the head of the Little Knife and White Earth Rivers probably have similar origin. The sloughs at the head of the White Earth are undoubtedly of glacial origin. The abrupt termination of the Little Knife River Valley, just south of Stanley, may be related in some way to the formation of the sloughs and lakes lying to the north and east of that place.

To the present writer it seems probable that these sloughs and lakes are due to blocking of valleys by pre-Altamont morainal drift such as may be seen along and south of the Great Northern Railway west of Stanley. Southwest of Stanley morainal deposits occur between the Little Knife and White Earth Valleys. In T. 155 N., Rs. 92 and 93 W., and T. 154 N., R. 93 W., is a strongly marked morainal ridge roughened with knolls and pitted with kettle holes, some of which contain ponds. It is possible that this topography continues north to the belt seen along the railway, though such is not known to be the case. Cuts in these deposits expose gray calcareous till, neither leached nor oxidized. Limestone pebbles are plentiful up to and on the surface, though most of the pebbles and boulders are of granite. This moraine extends westward to the White Earth Valley, and, crossing the valley in T. 155 N., it was found strongly developed on the upland to the west. It appears to have a northwesterly trend and is perhaps to be correlated with the morainal tract surrounding Temple, but it was not traversed so as to be definitely mapped. This tract appears to end at the northwest between 4 and 8 miles north of Ray, in T. 157 N., R. 97 W. The 50-foot contours of the Ray topographic map show no

[72] Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Mon. 38, pl. 6, 1899; Moraines and shore lines of the Lake Superior region: U. S. Geol. Survey Prof. Paper 154, pl. 1, fig. 15, 1929; Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, 1932.

[73] Willard, D. E., and Erickson, M. B., A survey of the coteaus of the Missouri: North Dakota Agr. Coll. Survey Second Bienn. Rept., pl. 3, 1904.

[74] Idem, p. 26.

[75] Leonard, A. G., The pre-Wisconsin drift of North Dakota: Jour. Geology, vol. 24, pp. 528–532, 1916.

[76] Wood, L. H., Preliminary report on Ward County and adjacent territory with special reference to the lignite: North Dakota Geol. Survey Second Bienn. Rept., p. 91, 1903.

continuation of this moraine to the west, though a few slight sags and swells were seen about 6 miles northwest of Ray and also southwest of Angie, in T. 158 N., R. 99 W. South of this the area is sharply dissected by the branches of the East Fork of Little Muddy Creek. Near the west line of T. 157 N., R. 99 W., a valley appears to be partly or wholly blocked by drift. Thence a belt of morainal knolls extends westward in T. 157 N., R. 100 W., to the Little Muddy Valley. This valley is broad and open above Marmon and also to the south, but for a mile or two below Marmon there is a well-developed moraine on the bottom land west of the stream.

The upland to the west has long smooth slopes, but its borders are sharply dissected. On this upland, where crossed from east to west and south to north, no trace of a moraine was seen except a few slight sags and swells on the divide between Sand and Cow Creeks. Morainal knolls and sags are encountered again a few miles northwest of Bonetraill post office, in T. 157 N., R. 102 W., and these are thought to be continuous on the southwest with the broad morainal belt that extends to and across the State line near Bull Butte, in T. 156 N., R. 104 W. This butte is a conical hill rising above the adjacent drift knolls and capped with drift and fragments of red clinker. On the top is a Coast and Geodetic Survey triangulation station at 2,530 feet above sea level. The body of this hill may be composed of shale, but there are morainal knolls and sags not far to the northeast and north and extending thence across the State line on to the lower ground to the northwest, masking the erosional topography.

TERMINAL MORAINE (?) IN ROOSEVELT AND VALLEY COUNTIES, MONTANA

The moraine plays out to the west and was not seen again in two traverses of the area between the Montana State line and the Big Muddy Valley. In its place throughout much of this area is a smooth little-dissected plain sloping gently northwestward to the broad preglacial trough in which lies Medicine Lake.

West of the Big Muddy Valley, in the old Fort Peck Indian Reservation (now Roosevelt County), but little evidence of morainal deposits to be correlated with the morainal belt under discussion was seen, although the area was traversed from north to south over ten or twelve different routes. C. M. Bauer, who studied the lignite deposits of the area, pointed out to the writer most of the occurrences here mentioned but stated that he failed to find any continuous moraine. C. D. Smith, who also studied part of this reservation, makes but very brief mention of the drift in his report.[77] Except on the steep eroded slopes, there is a thin sheet of glacial drift spread generally over the area of the reservation, covering the Tertiary and Cretaceous formations. In several parts Bauer found thicknesses of 10 to 40 feet of drift exposed, and with his observations those of the writer agree. The drift consists generally of calcareous gray or little oxidized clay with plentiful crystalline and limestone pebbles and boulders. There is also generally a large admixture of smoothly rounded and polished quartzite pebbles like those in the Flaxville gravel.

On the upland west of Homestead, in sec. 19, T. 31 N., R. 55 E., and sec. 25, T. 31 N., R. 54 E., and also in sec. 5, T. 29 N., R. 53 E., are a few isolated knobs rising abruptly 30 to 40 feet above the surrounding broad smooth plain that has been described[78] as a drift-filled preglacial valley (p. 21). So smooth is this plain that the knolls are conspicuous features. Those examined by the writer appear to be of glacial drift, although only the surface and material brought up by rodents could be examined. The tops are thickly strewn with crystalline and limestone boulders, mostly the former. These few knolls are in two groups at about 2,100 feet above sea level and about 12 to 14 miles apart. The groups seem to have no connection with each other or with definite morainal deposits. They may be merely isolated kames or may, perhaps, be correlative with the morainal belt. Northwest of the north group of knolls the surface rises gradually to 2,400 feet, and on this crest are slight sags and swells. An ice lobe may have lain in the Big Muddy Valley and the preglacial Missouri Valley without leaving more than these isolated knolls. The margin may have swung thence northward along the rising slope to the high land bordering Smoke Creek on the southwest at 2,400 feet.

In the northern part of the Hay Creek quadrangle and farther north, in the northern part of Ts. 31 and 32 N., R. 51 E., and extending northwest into T. 33 N., Rs. 49 and 50 E., there is an extensive nearly flat upland (a remnant of the Flaxville gravel plain or No. 1 bench) between the valleys of Smoke Creek and the Poplar River. On this there is a belt of morainal topography 12 to 15 miles long extending northwestward to the western edge of the upland near the north line of the old Fort Peck Indian Reservation. Slight sags appear in sec. 1, T. 31 N., R. 51 E. These continue west to a mild morainal topography of drift knolls extending north-northwest from sec. 5. In places, as at the triangulation station 2,753 feet above sea level in the southwestern part of T. 33 N., R. 50 E., in southeastern Daniels County, there are strongly marked knobs and kettle holes. From this point the belt was traced west-northwestward to the edge of the upland overlooking the Poplar Valley. Some swells

[77] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, pp. 43-44, 1910.

[78] Bauer, C. M., A sketch of the late Tertiary history of the upper Missouri River: Jour. Geology, vol. 23, pp. 53-54, 1915.

appear to continue down the long dissected slope. A line of scattered low knolls also extends southwestward down the valley slope nearly to the Poplar River, about 3 miles southeast of Cusker's ranch. Some of these knolls may consist of shale, but one examined near the road appears to be drift. The surfaces of the knolls on the upland show mostly quartzite gravel, but pebbles of igneous crystalline rocks and limestone are intermingled with the quartzite.

On the lower land to the north, in sec. 35, T. 32 N., R. 50 E., there is a sinuous eskerlike ridge 10 to 30 feet in height, with an uneven knobbed crest. A line of swells appears to extend thence some distance southeastward, and there is some suggestion of connection with the moraine to the west. A well drilled on this lower land in sec. 18, T. 33 N., R. 50 E., is said to have penetrated 24 feet of clay (drift), above gravel and to have ended in gravel at a depth of 45 feet. A well on the upland in or near the moraine is said to have penetrated 40 feet of gravel below the drift clay.

An ice lobe may have lain in the Poplar Valley for a time, and the margin may have swung thence northwestward up onto and along the upland crest northeast of Boxelder Creek, through adjacent parts of Ts. 30 and 31 N., R. 49 E., and T. 31 N., R. 48 E., where there is a belt of knolls and slight marshy sags. These features, however, fade out after extending a few miles toward the northwest. Most of the material is quartzite gravel, but igneous crystalline pebbles and boulders are generally intermingled. This upland stands 500 feet or more above the bottom of the Poplar Valley to the northeast, and the long valley slopes are sharply dissected.

When the ice front was in this position its margin, if having a general northwesterly trend, would probably lie along the slope and crest south of Cottonwood Creek in T. 31 N., although no morainal features were noted where it was crossed. For some miles south of this crest hardly any crystalline or limestone drift material is mingled with the quartzite pebbles. One interesting feature is a series of cols cutting through the crest of the upland and leading to the heads of the branches of Tule Valley and Wolf Creek. One of these, traversed by the road leading down the east valley of the East Fork of Wolf Creek, is 40 to 50 feet deep. A person ascending the 300-foot dissected slope south of Cottonwood Creek is surprised at the top to find himself in the head of a valley leading southward rather than on the broad smooth upland.

A more notable pass is that between the heads of Cottonwood and Little Porcupine Creeks in sec. 34, T. 32 N., R. 44 E. Here the broad, nearly flat valley floors are continuous, and Little Porcupine Creek has evidently captured some of the headwaters of the other stream. This pass must have afforded outlet for glacial water at certain stages when outlet to the Poplar Valley was blocked by ice, as, for instance, when the ice front was at or near the line under discussion. Little Porcupine Creek, to the south, traverses a great trough cut in the shale to a depth of nearly 300 feet. On the upland northwest of the pass above mentioned, in T. 33 N., R. 43 E., and adjacent tracts, is an area characterized by knolls and ridges whose contours suggest morainal deposits, but here again there is a suspicion that they may really be erosion remnants of the higher part of the Flaxville gravel deposit. The only material exposed on these so far as seen is quartzite gravel. A single granite boulder was noted in the vicinity, though scattered boulders were seen farther south. The belt extends northwestward toward Avondale.

About 20 miles farther northwest on the upland south of Opheim a similar belt of morainelike knolls, possibly a continuation of that near Avondale, was crossed. Here again the knolls so far as examined appear to be composed entirely of quartzite gravel, though scattered granite boulders occur both to the north and south. For a long distance westward from the line thus traced no suggestion of glacial moraines was seen, though the area was traversed by the writer in general north-south directions at intervals of 6 to 15 miles. Neither do A. J. Collier and H. H. Bennett, who have examined this area, report any such occurrences.

The area west of Porcupine Creek comprises the basins of Rock and Frenchman Creeks, which are cut principally in the soft shales of the Montana group. No remnants of uplands underlain by the Fort Union beds and capped with the Flaxville gravel are preserved south of the Wood Mountain plateau of southern Saskatchewan. The general level is lower, and it may be supposed that, if the ice front lay along the uplands to the northeast as traced, a broad lobe would have extended farther south in western Valley County.

There are knolls in places below the western edge of the upland in R. 37 and 38, but the belt is difficult to traverse and has not been carefully examined. It is possible that the ice front extended on the low ground to and across the line of the Milk River west of Hinsdale. Certain features shown on the Hinsdale topographic map, 3 to 5 miles northeast of Hinsdale, in secs. 21–23, T. 31 N., R. 36 E., suggest the blocking of the Rock Creek Valley by morainal deposits.

TERMINAL MORAINE IN PHILLIPS AND BLAINE COUNTIES, MONTANA

There are also drift knolls near the railway west of Hinsdale. A ridge in the Larb Creek Valley 2 miles south of Beaverton suggests that the ice front may have crowded into the mouth of this valley and forced the drainage to flow southward through the pass in T.

26 N. leading to Timber Creek. West of this valley there is also a belt of low drift knolls between the Great Northern Railway and the foot of the bluff. Some low swells south of Beaver Creek along the Roosevelt Highway and the Great Northern Railway, west of Saco, may be morainal. One of these in sec. 32 (see Saco topographic map) appears to have been wholly removed for railway ballast. Similar kame-like knobs are to be seen near the foot of the west slope of the hills east of Beaver Creek and, as shown at the south margin of the Bowdoin quadrangle, in secs. 21, 22, 27, and 28, T. 29 N., R. 32 E., about 10 miles south of the railway, a group of morainelike knobs 20 to 60 feet in height obstruct the broad bottom of the valley.

It is possible that some of the low drift ridges that lie across the old buried valley of the Missouri River south of Bowdoin village and Lake Bowdoin (see Bowdoin topographic map) are morainal, but there is no strongly marked morainal topography. At one place where the south canal cuts through a narrow place in the ridge, in secs. 11 and 12, T. 30 N., R. 31 E., 5 to 10 feet of pebbly drift overlies what appears to be fine wind-blown clayey sand. Such swells also occur north and east of Lake Bowdoin (p. 112). The upland slopes to the south are considerably more dissected than those north of Lake Bowdoin. The possibility that the southern limit of the early Wisconsin ice advance passed somewhere in this vicinity is also suggested by conditions found south of Malta and farther west. A rough, bouldery morainal deposit lies along the south slope of Malta above the south canal, and a gravel pit in this deposit exposes very stony, poorly sorted subangular crystalline pebbles and boulders. The uneven topography continues for about 2 miles south; beyond this the surface for a few miles is smoother. At 8 or 9 miles south of Malta, in T. 29 N., R. 30 E., there is another belt of morainal hills and marshy lake basins, which is crossed by the roads leading to Regina and to Flat Creek. On one of the abrupt boulder-strewn hills is a United States Geological Survey triangulation station. Though these appear clearly to be marginal glacial moraines, their continuations either to the northeast or southwest are not well marked. A faint morainal belt is traceable westward to the Fort Belknap Indian Reservation through T. 29 N., as noted below (p. 111). Though no marginal moraine has yet been traced southwestward through the country northwest of Beaver Creek, yet the relations of the moraine near the Little Rocky Mountains seem to indicate that the limit of the early Wisconsin ice advance must extend through this area. After passing Alkali Creek on the road southwest from Malta toward Zortman no signs of a moraine were seen until Little Warm Springs Creek was passed. In the southwestern part of T. 26 N., R. 27 E., a low morainal ridge, well sprinkled with quartzite pebbles and boulders, extends westward across the road and breaks up into a belt of knolls which continue westward across No. 2 bench to the vicinity of the gap through which Little Warm Springs Creek crosses the ridge of Judith River sandstone near the east line of the Fort Belknap Indian Reservation. From this locality a hilly belt strewn with abundant crystalline boulders extends northwestward through T. 26 N., R. 26 E., on the low ground bordering the northeast side of the sandstone ridge. This appears to mark the limit of the early Wisconsin ice invasion.

When the ice front stood in this position (pl. 35) waters held between the glacier and the Little Rocky Mountains must have escaped southward through the sag which is now traversed by an irrigation ditch and in which is the reservoir held by the dam at the Malta road, in sec. 11, T. 25 N., R. 26 E. Doubtless it was after a slight recession of the ice front, if not at the earlier ice invasion, that Warm Springs Creek cut through the sandstone ridge, making the narrow gorge 250 feet or more in depth in the SE. ¼ sec. 1, T. 26 N., R. 25 E. The ridge in sec. 1 north of the gorge now separates this stream from what appears to have been its former broad valley.

From this valley westward the margin of the early Wisconsin drift was traced by the writer with some care clear across the reservation (pl. 1) in 1921, when A. J. Collier and S. H. Cathcart were making their detailed geological survey.[79]

In the NW. ¼ sec. 34, T. 27 N., R. 25 E., are pillars of sandstone which appear not to have been overridden by the early Wisconsin ice, but about three-quarters of a mile north of these the moraine is found lying along the upper slope just beyond the edge of No. 1 bench. The ice crowded southward on top of the bench to the knolls in the NE. ¼ NW. ¼ sec. 28 up to 3,500 feet above sea level. In the valley to the west a small lobe extended half to three-quarters of a mile farther south, and west of this the ice barely reached the top at the north end of No. 1 bench, in the N. ½ sec. 25, T. 27 N., R. 24 E. The limit of the advance is marked by a marginal drift ridge above and a quarter to half a mile north of the crest of the sandstone bluff that borders the Lodgepole Creek Valley. On the lower ground to the west the ice extended 1 to 2 miles farther south, and the limit of drift runs first southwest, then west to Hays. There are boulders, till, and a few ponds in this part, but no well-marked moraine.

West of Hays the drift limit is a sinuous line through the southern tier of sections of T. 27 N., R. 23 E. This lies north of the sag along which passes the irrigation ditch running to the reservoir 2 miles west of Hays. Beyond the south dike of the

[79] Collier, A. J., Geology of the Fort Belknap Indian Reservation and Little Rocky Mountains, Mont. (in preparation).

reservoir the sag is continuous to the west. Evidently it was by this sag that waters ponded by the glacier in the Peoples Creek Valley escaped. Apparently the ice was bordered by a westward-flowing stream and did not crowd up onto the dissected north end of the high bench. In R. 22 E., however, a lobe extended southward 2 to 3 miles on the lower land in the former valley of Section Creek, and a mild moraine is traceable westward from the middle of the south line of sec. 12 through secs. 11 and 10 to and across the reservation boundary. The present course of Section Creek is probably due to diversion westward by the ice front.

At its most southerly point the moraine has an altitude of about 3,000 feet. About 12 miles in a direction somewhat east of north from this point the higher of the Twin Buttes (pl. 36 *A*) rises to an altitude of 3,850 feet, or about 850 feet higher than the plain at its base and the moraine at its most southerly point. Inasmuch as drift pebbles were found on the top of this butte, it appears that the ice must have been at least 850 feet thick within 12 miles of its limit. This butte is about 7 miles farther north and 350 feet higher than the limit of the ice advance on the high benches north of Lodgepole. The top of this butte is about 1,500 feet higher than the flat along the Milk River 20 to 25 miles to the north and northeast. Probably there was a considerable thickness of ice even on top of the Twin Buttes, but if it is supposed that the highest point was barely covered and if a southward slope of only 20 feet to the mile is assumed for the surface of the glacier, there must have been about 1,000 feet of ice on top of Snake Butte and at least 2,000 feet of ice over the flats along the Milk River.

It is probable that the Little Rocky and Bearpaw Mountains were heavily covered with snow during both the earlier and later stages of glaciation, but neither Collier, Cathcart, nor Weed and Pirsson report evidence of local glaciation in the Little Rocky Mountains, nor did Weed report any in his descriptions of the Bearpaw Mountains.[80] No suggestion of local glaciation was found by the present writer on the short traverses which he made in these mountains. At several points on the mountains scratches which closely resembled glacial striae were noted on small exposed surfaces of limestone. Inasmuch as these were seen only in trails which had been used for dragging logs and in positions where no other phenomena indicated glaciation it was concluded that they were not glacial striae.

West of the Fort Belknap Indian Reservation the limit of the drift runs somewhat west of north 20 to 25 miles to the vicinity of Eagle Butte, in sec. 6, T. 29 N., R. 21 E., the most northeasterly outlier of the Bearpaw Mountains. In this part the limit of the drift as shown on Plate 35 has not been traversed by the writer but is approximated from Bowen's map of the Cleveland coal field.[81] On this map several lines are shown as marking "Boundary of areas covered by drift or bench gravel." It is assumed by the present writer that the most easterly of those southeast of Eagle Butte is probably at or near the limit of glacial drift.

Eagle Butte was surrounded by the ice on the east, north, and west. For about a mile east of the butte the main road runs on a gravel terrace bordering the south front of a well-marked boulder-strewn moraine 50 to 60 feet high. (See pl. 36 *B*.)

The altitude here is about 3,500 feet (barometric). Scattered boulders were also found on the lower slopes of Eagle Butte up to a few hundred feet above the base. Southwest of this butte there are unglaciated curiously weathered ledges of sandstone not far south of the road to Cleveland. The actual limit of the drift across the foothills west of Eagle Butte was located by the writer at only a few points; between these the limit as shown on the map is only approximate.

About 2½ miles north of Lloyd the road, after crossing the craggy ridge of igneous rock, runs north down to the margin of the drift at about 3,820 feet (barometric) as noted by the present writer. About 5 miles northeast of this point glacial pebbles and boulders, one measuring 2 by 3 by 4 feet, were found on top of Bean Butte, a mass of igneous rock that rises abruptly 400 to 500 feet above the plain in sec. 5, T. 30 N., R. 19 E. It is possible that the highest erratics—those found by Reeves east and west of Beaver Creek in T. 30 N., Rs. 15 and 17 E., at 3,890 and 3,898 feet—were deposited by the pre-Wisconsin ice sheet.

In the course of his mapping about the north and west flanks of the Bearpaw Mountains in 1924, Reeves made some observations on the drift which have been communicated to the writer. The "southern limit of areas covered by glacial drift" shown by Reeves[82] is not the outer limit of the ice advance but the limit of areas where the bedrock is almost wholly concealed beneath drift. The ice advanced southward nearly across T. 30 N. and crowded against the craggy, broken north face of the mountains.

Owing to the relatively short distance from the Bearpaw Mountains to the Milk River and the consequent high gradient of the streams the tract between the mountains and the river has been considerably

[80] Weed, W. H., and Pirsson, L. V., The geology of the Little Rocky Mountains: Jour. Geology, vol. 4, pp. 401–402, 1896; The Bearpaw Mountains, Mont.: Am. Jour. Sci., 4th ser., vol. 1, pp. 283–301, 351–362; vol. 2, pp. 136–148, 188–199, 1896.

[81] Bowen, C. F., The Cleveland coal field, Blaine County, Mont.: U. S. Geol. Survey Bull. 541, pl. 20, 1914.

[82] Reeves, Frank, The structure of the Bearpaw Mountains, Mont.: Am. Jour. Sci., 5th ser., vol. 8, fig. 2, p. 299, 1924; Geology and oil and gas resources of the faulted area south of the Bearpaw Mountains. Mont.: U. S. Geol. Survey Bull. 751, pl. 12, 1924.

dissected by sharp coulees 50 to 200 feet in depth, since the early Wisconsin ice disappeared. In this area thicknesses of 10 to 50 feet of glacial till are exposed at many places in the steep sides of the coulees and in stream banks, and in some of these places the full thickness of the drift is not uncovered.

TERMINAL MORAINE IN HILL AND CHOUTEAU COUNTIES, MONTANA

The Beaver Creek Valley, in the old Fort Assinniboine Military Reservation, has been filled with glacial drift southward to a point about 16 miles south of Havre in the southern part of T. 30 N., R. 16 E., and partly reexcavated. Thicknesses of 50 to 60 feet or more of buff pebbly clay till are exposed at many places along this valley. The ice appears to have crowded against the north slopes of the craggy peaks of igneous rock east and west of this valley but could not overtop them. Reeves found glacial boulders up to 3,898 feet above sea level between Little Boxelder and Beaver Creeks in sec. 6, T. 30 N., R. 17 E., and up to 3,890 feet west of Beaver Creek, in sec. 26, T. 30 N., R. 15 E.

West of the Bearpaw Mountains the ice advanced much farther south along the old valley of the Missouri River and on the plain to the west. Two traverses into the foothills bordering the west side of the mountains were made by the writer in 1920, but the limit of the drift was not mapped. Four miles east of Boxelder is Square Butte, a prominent landmark rising 900 to 1,000 feet above the nearly flat plain at its western base. It is capped with a sill of hard gray intrusive crystalline rock whose surface is nearly flat. This top, which is about 3,650 feet above sea level, is sprinkled with glacial boulders of granite and limestone. In several places smooth bare surfaces of the rock retain the glacial polish and show glacial striae. Those near the south edge of the top trend S. 8° E., and those a little farther east trend S. 4° W. The divergence is probably due to deflection of the basal ice by the bold cliffs around the sides of the butte. Evidently the ice was thick enough to move readily across the top of the butte. Thus, it must have been more than 1,000 feet thick. The limit of the drift is about a mile east of Square Butte, as the hilltops beyond are very rough in that direction. Reeves,[83] in 1924, found drift to extend several miles farther east up the Boxelder Valley, and south of Duck Creek the drift limit lies across the remnant of a high gravelly bench. At a point about 10 miles northeast of Sandy Creek, near Gorman Creek, a terminal moraine, marked by sharp bouldery knolls, sags, and ponds, was seen by the present writer. This appeared to extend northward up onto a remnant of a high bench west of Centennial Mountain.

South of T. 29 N. the drift that extends eastward to the limit mapped by Bowen and Reeves appears to represent a somewhat earlier stage of glaciation (Iowan or Illinoian (?), pp. 79–80). It is quite possible that some of the highest erratics noted above were deposited by this earlier and more extensive ice sheet.

Tracing the moraine from west to east in southwestern Chouteau County, Calhoun[84] wrote:

> The character of the moraine changes abruptly after it passes over Teton Ridge. There is no longer a well-defined ridgelike edge, but more often a low, broad rise, usually too slight to be noticeable.
>
> This moraine may be traced, with few breaks, directly across the country from Teton Ridge to the Bearpaws. It is better developed than the [outer] terminal moraine, which, while having the essential elements of the kettle moraine, often shows them in a feeble state of development. South of Tunis the moraine is between 3 and 4 miles wide and is covered with lakes and lake basins, some of which extend 50 feet below the general level. This moraine is again seen, though not so clearly defined, along the north bank of the Missouri, near the mouth of the Teton. Between the headwaters of Big and Little Sandy Creeks there is another excellent example of morainic topography, continuing to the foot of the west slope of the Bearpaws.

There are low morainal swells near the railway at and south of Verona station, also south of the automobile road that follows the old railway grade for some distance southwestward between Verona and Loma. The ice front probably lay on the bench between the Teton and Missouri Rivers as far west as Tunis and Carter, and from the vicinity of Floweree a belt of low swells extends westward to the outer limit of the glacial drift, near the northeast corner of sec. 36, T. 23 N., R. 3 E. At this place, 15 miles north of Great Falls, the moraine front is fairly definite where the surface rises northward with low undulations sprinkled with granitic boulders. The relations of the deposits exposed in the railway cut west of Fort Benton are described on page 66.

RELATIONS OF THE GREAT FALLS LOBE

Near the Teton River, 6 or 8 miles northeast of Choteau, Teton County, the margin of the Keewatin drift curves and extends thence northward in a sinuous course to the international boundary near the northeast corner of the Blackfeet Indian Reservation, in Glacier County. This line, together with that described above, delimits the area of the most southwesterly lobe of the great Keewatin ice sheet. (See pls. 1 and 29.) The breadth of this lobe, measured on a line drawn in a northwesterly direction from the Bearpaw Mountains near Square Butte to the international boundary at the point indicated, is approximately 125 miles, and the length of the lobe, measured in a southwesterly direction from this line to the mo-

[83] Personal communication.

[84] Calhoun, F. H. H., op. cit., p. 27; see also pl. 5.

raine on the Teton River east of Farmington, Teton County, is about 66 miles. The lobe that extended southward to the location of the Great Northern Railway southeast of Great Falls at the Illinoian or Iowan (?) stage of glaciation probably had about the same width but was about 12 miles longer. The area of this great lobe at the Wisconsin stage was about 5,600 square miles. This is between three and four times the area of the great Malaspina Glacier of Alaska,[85] which covers about 1,500 square miles. This lobe in Montana was nearly as large as the combined area of Connecticut and Rhode Island.

The data here given concerning the position and character of the marginal glacial deposits along the west side of this great lobate area from the Teton River northward to the Canadian boundary are taken almost entirely from the field maps and notes of Eugene Stebinger, made in connection with detailed stratigraphic work in 1911 to 1916. The sinuosities of the glacial margin in Teton and Pondera Counties were due in large measure to the alternation of salients of the remnants of the high gravel-covered No. 1 and No. 2 benches, described above (p. 46), with broad valley plains and embayments where the surface of the land had been reduced to lower levels by pre-Wisconsin erosion. North of the Great Northern Railway and east of Cut Bank the rim of Virgelle sandstone rises to a height of 500 to 600 feet above the plain to the east. This bold eastward-facing escarpment and the high upland to the west controlled the deployment of the ice in adjacent parts of Toole and Glacier Counties. The height of these topographic features was sufficient to stop the advance of the ice front through an extent of 75 miles from north to south. The significance of this topographic control of the ice movement warrants a somewhat detailed presentation.

TERMINAL MORAINE IN TETON AND PONDERA COUNTIES, MONTANA

An observer looking eastward from the flat plain (No. 3 bench?) on which stands the village of Farmington can see the western edge of the drift sheet extending northward as a broad ridge 100 feet or more in height at the east edge of the flat between the Teton River and Muddy Creek, about 5 miles east of the railway. For several miles along the road east to Collins the bouldery surface is marked by mild sags and swells. Stebinger's notes record exposures of 50 to 200 feet of glacial till along the Teton River west of Collins and of 20 to 100 feet of till on Muddy Creek. On the north slope of Teton Ridge, which is about 500 feet high (4,200 to 4,300 feet above sea level) glacial boulders were noted up to about 3,900 feet. Some of these may be berg-transported, as, according to Calhoun, this was about the upper limit of water ponded by the ice in the upper Teton Valley.

In Pondera Basin, in Ts. 27 and 28 N., Rs. 4 and 5 W., a lobe of the ice extended on the low ground to a point 12 miles west of the railway near Conrad. On the gravel-capped ridge (No. 1 bench) to the south, however, the glacier was able to advance only to a point 8 miles farther east (about 3,800 feet above sea level), and here water ponded along the glacial margin cut a trench 60 to 80 feet deep through the crest of the ridge. As the ice front to the south receded this channel was extended southeastward to Muddy Creek as Kropp's Coulee. A sharp reentrant in the glacial margin was also caused by the wedge-like ridge north of the Pondera Basin, which is capped with No. 1 gravel. The head of this reentrant was about 4 miles west of Conrad. Calhoun found in the Pondera Basin a "well-defined moraine of pronounced topography," with lakes as numerous as in the moraine near the international boundary.

Calhoun[86] reasoned from the height of the ridges north and south of the Pondera Basin, which were not overridden, that the westward slope of the surface of the ice in the basin could not have been more than 30 feet to the mile.

South of Williams station another reentrant in the glacial margin was caused by the butte in sec. 32, T. 29 N., R. 4 W., on which is the triangulation station at 4,165 feet above sea level. Drift pebbles are reported to have been found on the top of this butte. A channel formed by marginal drainage near by has an altitude of about 4,000 feet. North of this locality the drift margin swings 15 miles or more to the west, in the broad basin traversed by the lower courses of Birch Creek and Two Medicine Creek. (See pl. 1.) On the former stream the ice advanced westward onto the broad gravel-covered Birch Creek flat (No. 3 bench), which is about 30 feet above the flood plain. Here there is not a well-defined terminal moraine. Water must have been ponded in all these valleys up to the height of the lowest available outlets, and in many places laminated lacustrine clay is exposed in the creek banks overlying the mountain gravel west of the glacial limit. Berg-transported boulders of granite were noted by the writer along the Park to Park Highway between 3,900 and 4,000 feet above sea level near Birch Creek, north of Dupuyer.

Thus far north there is no contiguity between the Keewatin drift and that of the mountain glaciers. In the Birch Creek Valley, however, the mountain ice and the Keewatin ice approached within 12 miles of each other, and in T. 31 N., R. 7 W., 15 miles northwest of Valier, only the ridge about 1½ miles wide, which is capped in part with No. 1 bench gravel, sep-

[85] Russell, I. C., Malaspina Glacier: Jour. Geology, vol. 1, p. 224, 1893. The Malaspina glacier measures 20 to 25 miles from front to back and 70 miles from east to west along the coast.

[86] Calhoun, F. H. H., op. cit., p. 25.

arated the Keewatin ice from the Two Medicine Glacier.

TERMINAL MORAINE IN GLACIER AND TOOLE COUNTIES, MONTANA, AND SOUTHERN ALBERTA, CANADA

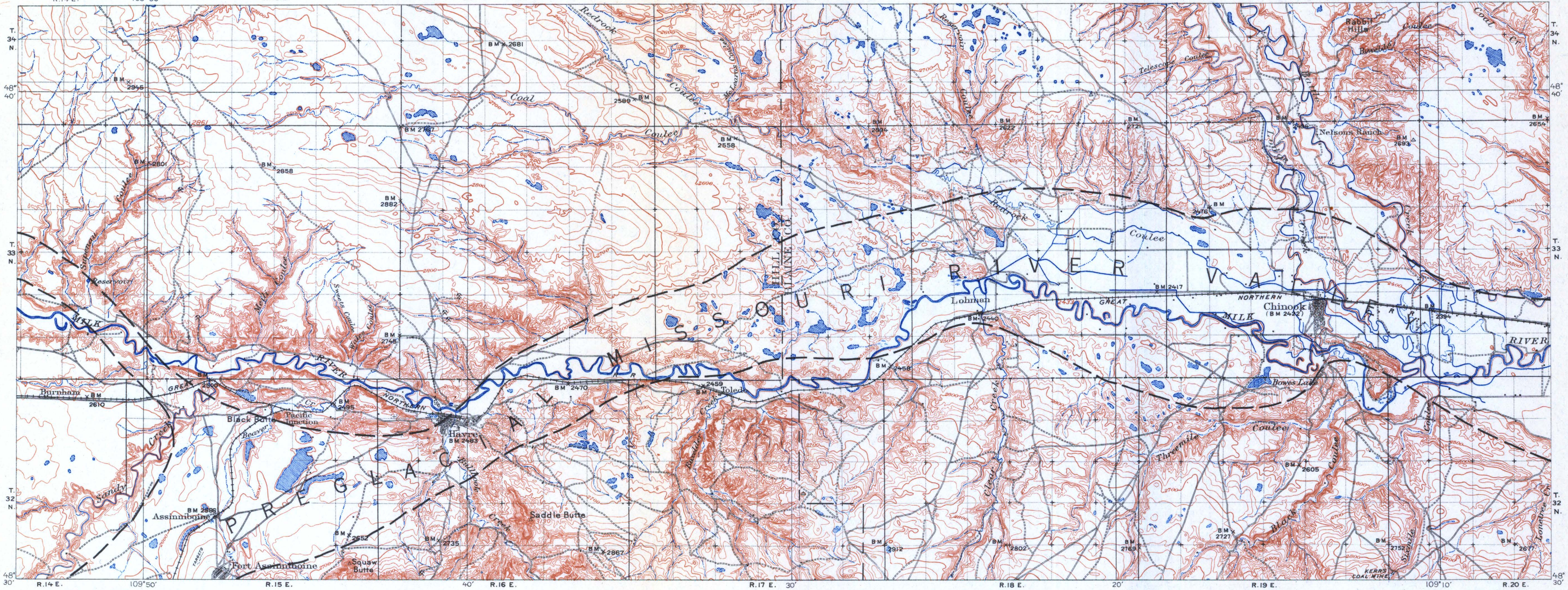
North of Two Medicine Creek the margin of the Keewatin drift extends northeastward past the ponds in sec. 21, T. 32 N., R. 6 W., to the gorge of Cut Bank Creek (near SE. corner sec. 6, T. 32 N., R. 5 W.) about 7 miles south of Cut Bank village. (See pl. 37.) There is no definite terminal moraine between the two streams east of Cut Bank Creek. The ice was stopped by hills rising 4,000 to 4,100 feet above sea level, but it advanced on the lower ground to the northeast and southwest so that a reentrant 4 miles deep was formed. The margin is marked by a small but definite sinuous ridge in most places on these hills. Within a few miles this margin varies 400 feet in altitude—that is, between 3,700 and 4,100 feet. (See Cut Bank topographic map.) About 12 feet of till is exposed in a Great Northern Railway cut west of Baltic, and greater thicknesses are seen in the sides of coulees. North of the Great Northern Railway the Virgelle sandstone forms an irregularly dissected, eastward-facing escarpment, which extends in a sinuous course northward nearly to the international boundary. This reaches a maximum altitude of 4,300 feet about 20 miles northeast of Cut Bank, in sec. 5, T. 35 N., R. 3 W., and it varies in height from 600 to nearly 1,000 feet above the low ground to the east that is traversed by the Sweet Grass branch of the Great Northern Railway. In this part rough, knolled, and pitted morainal topography is found throughout much of a belt ranging from 2 to 8 miles in width, lying partly above and partly below the escarpment.

The distribution of the moraine shows that between the high point mentioned above and the main line of the Great Northern Railway the ice crowded westward 1 to 4 miles on the upland above the crest of the escarpment. Ravines cutting the escarpment expose 20 to 40 feet of till, and in places the former irregularities appear wholly "drowned" in drift. North of the highest point above noted the escarpment lowers toward the Milk River, and the moraine turns sharply and extends in a broad curve, first westward in T. 36 N., Rs. 3 to 5 W., then northward in Ts. 36 and 47 N., Rs. 5 and 6 W., until the outer margin is less than half a mile south of the Canadian boundary. This shows that a minor lobe of the ice nearly 20 miles in width advanced southward onto the upland in northwestern Toole County and northeastern Glacier County and overtopped hills 4,100 to nearly 4,300 feet above sea level. In this part the moraine ranges from 2 to 9 miles in width and is marked by many knobs and hills interspersed with numerous small lakes and intermittent ponds. T. 36 N., R. 4 W., includes some of the roughest parts of the moraine belt.

The outer front of the moraine in this part is not a striking feature of the landscape as seen in a general view. It is clearly traceable, however, and in many places appears as a distinct bouldery ridge 5 to 50 feet in height running in a sinuous course up and down over the hills and across the hollows and showing in detail the relations of the ice margin to the preexisting erosional topography. No glacial outwash gravel was noted at any point along the outer margin of the moraine north of the railway unless the fine stratified gravel exposed below the flat west of Hay Lake is of that origin. The gravel-capped hill crossed by the margin of the drift in the SW. ¼ sec. 18, T. 36 N., R. 5 W., appears to be a remnant of one of the high benches, as the gravel consists wholly of pebbles from the Rocky Mountains. The inner margin of the moraine is very indefinite, and the boundary is drawn more or less arbitrarily to include the roughened morainal topography. The area to the north is mostly well covered with till.

About 25 miles north of Cut Bank and less than half a mile south of the international boundary, in sec. 2, T. 37 N., R. 6 W., the outer margin of the drift swings to the west again and climbs to the top of a gravel-capped ridge, a remnant of No. 1 bench. (See pl. 38 *A*.) The crest of this ridge is one of the highest points covered by the ice west of the Adirondack Mountains. Here it took an altitude which is now about 4,400 feet to stop the advance of the ice. At the north flanks of the Bearpaw and Little Rocky Mountains the limit reached is about 3,500 feet. The ice in the valley of the South Fork of the Milk River crowded against the north slope of the ridge and laid its moraine along the narrow crest but did not cross the divide. It advanced up the valley to the sharp bend 4 miles northeast of Landslide Butte. Here the drift margin curves to the northwest again and in 7 miles more crosses the boundary line into Alberta at the northeast corner of sec. 6, T. 37 N., R. 8 W.

A small lake was held in the valley of the South Fork of the Milk River, and this discharged southeastward through Antelope Draw to glacial Lake Cut Bank. The bottom of this outlet is now 4,000 feet above sea level, and many boulders of pre-Cambrian granite from Canada dropped from bergs floating on this lake are found scattered on the slopes northeast, north, and northwest of Landslide Butte. Most of these are below the 4,000-foot level, but a few, as on Flag Butte, lie at 4,000 to 4,200 feet. Possibly the outlet was at first 100 to 200 feet higher than now and was cut deeper by the outflowing water. Stebinger's notes suggest the possibility that either the Wisconsin ice or an earlier sheet advanced a mile beyond the well-



Base from U. S. Geological Survey maps of Thibedeau Lake and Zurich quadrangles Surveyed in 1902 and 1909

TOPOGRAPHIC MAP OF PARTS OF HILL AND BLAINE COUNTIES, MONT., SHOWING LOCATION OF THE PREGLACIAL MISSOURI RIVER VALLEY

By Wm. C. Alden after F. H. H. Calhoun

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

marked outer limit of the moraine, for a sharp ridge in sec. 30, T. 37 N., R. 7 W., was found to be thickly covered with drift. From 50 to 60 feet of till is exposed where the river cuts through the moraine.

In 1920 the writer crossed No. 2 bench south of the North Fork of Milk River and west of Shanks Lake in adjacent parts of T. 1 N., Rs. 21 and 22 W., Alberta, and found no Keewatin drift on the bench gravel whose surface is about 4,300 to 4,350 feet above sea level near the international boundary. North of the river the road to Magrath runs for several miles through a belt of sags and swells with numerous ponds. Evidently the terminal moraine passes westward through T. 2 N., R. 22 W. About 12 miles to the southwest it recrosses the boundary from sec. 6, T. 1 N., R. 23 W., Alberta, into sec. 5, T. 37 N., R. 11 W., Montana, on the Hudson Bay divide northwest of the North Fork of the Milk River. (See international boundary map, sheet 21; also Browning topographic map.) At the head of Emigrant Gap Stebinger found " very heavy moraine " with " kamelike masses " 80 to 100 feet high and rising to 4,500 feet or more. This gap and another to the east permitted flow of the glacial waters to Milk River. For 4 miles southwest of Emigrant Gap the front of the Keewatin ice lay along the north slope of the ridge, and drift was found up to 4,685 feet.[87] Calhoun describes that part of the moraine north of the international boundary as follows:

> Northeast of this point [Emigrant Gap] the ice reached the flat top of Milk River Ridge and spread over it to the south, forming a wide moraine characterized by lakes, undrained depressions, and hummocky topography of strong relief, the difference between the tops of the knolls and the bottom of the kettles in many cases being 120 feet. At the point where the moraine swings to the top of the ridge it has an altitude of about 4,720 feet, and at a point 6 miles to the west, of about 4,300 feet; this gives a slope of 70 feet per mile to the edge of the ice of the northeastern ice sheet.
>
> Although the ice reached the summit of Milk River Ridge, it did not move for any considerable distance across its plateaulike top. The ridge separated the ice into two parts, one lobe entering St. Mary Valley while the main sheet was forced farther east, causing a great reentrant to be formed.

East of the road leading from the gap at Hall's ranch (now Galbraith's) north to the United States customhouse (formerly Galbraith's ranch) the ice front extended northwestward across the valley. The exact western limit of the Keewatin ice, however, is not very plainly marked, for here both the Keewatin ice sheet and the lobe of the St. Mary Glacier heading in the mountains to the west deposited morainal drift. Some of the boulders of pre-Cambrian granite from the northeast scattered over drift of the mountain ice may have been dropped from bergs floating in a lake held between the two glaciers after the mountain ice had begun to retreat. Such a lake would find an outlet to the Milk River first through the gap at Galbraith's ranch (formerly Hall's) and later through Emigrant Gap, which is now traversed by the St. Mary Canal. In 1914 Clifton S. Corbett, assisting Mr. Stebinger, found crystalline boulders of Keewatin drift on a knob in or near the NW. ¼ sec. 24, T. 37 N., R. 13 W., about 3 miles southwest of the United States customhouse and 3 miles east of Spider Lake.

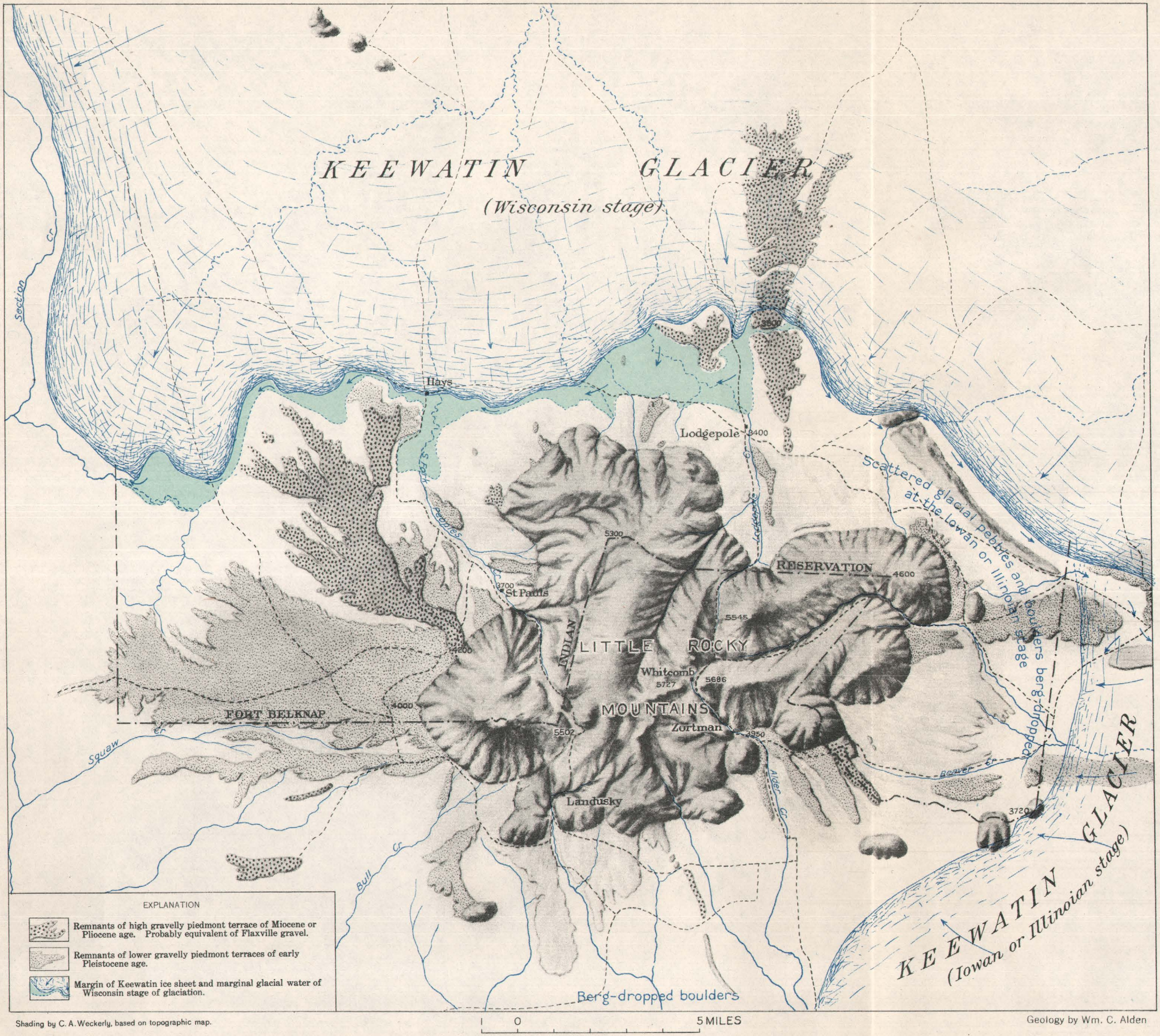
[87] Calhoun, F. H. H., op. cit., p. 24.

About 3 miles northwest of the United States customhouse the margin of the Keewatin drift curves about the north end of the ridge about half a mile south of the boundary, at 4,600 feet above sea level, and runs southwestward down the slope to the St. Mary River. In this valley the Keewatin ice extended 1½ miles south of the boundary to the middle of sec. 8, T. 37 N., R. 13 W. For about a mile on the east side of the river and for nearly 2 miles on the west side there are remnants of an outwash terrace sloping southward up the valley from the margin. This terrace is capped with gravel containing pebbles of pre-Cambrian granite from the northeast, and in places the gravel overlies till deposited by the St. Mary Glacier and containing pebbles and boulders of mountain rocks only. The relations seem to indicate that after the front of the St. Mary Glacier had receded to an unknown distance gravel was washed from the ice dam formed by the front of the Keewatin ice sheet into a lake held in the valley. The outlet of the lake was eastward through the Spider Lake gap, now traversed by the irrigation canal. Similar relations are indicated by cut banks farther north which expose Keewatin till overlying till of the mountain ice. One of these, examined by the writer in 1912 and again in 1920, showed the following section:

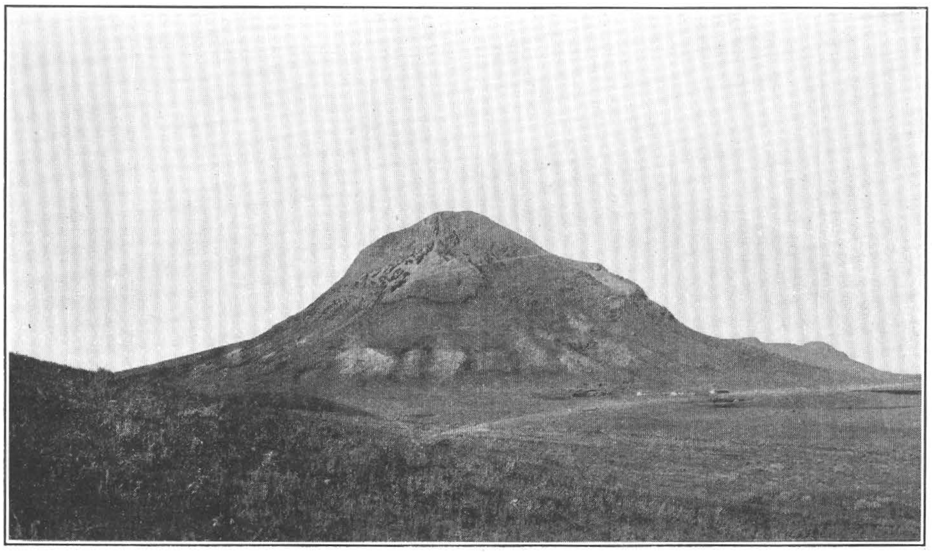
Section of drift on St. Mary River at international boundary

	Feet
Drift of Keewatin ice sheet: Buff pebbly clay. Most of the pebbles are quartzite and argillite from the Rocky Mountains; intermingled with these are many pebbles of pre-Cambrian crystalline rocks from the northeast	50
Drift of St. Mary Glacier: Very stony till containing pebbles of mountain rocks only, including limestone and diorite, but no pebbles of pre-Cambrian crystalline rocks from the northeast	50
Cretaceous shale, upturned and eroded.	

When examined in 1912 the shale was not exposed, and the lower till was underlain by 12 to 15 feet of waterworn quartzite gravel from the mountains. No glacial striations were seen on any of the stones examined, some of which were as much as 1½ feet in diameter. Between 1912 and 1920 the gravel was washed away and the shale was exposed. Neither in 1912 nor in 1920 was any trace seen of an intercalated soil or weathered zone such as would indicate exposure of the mountain drift for any considerable time before it was covered by the Keewatin till. The possibility

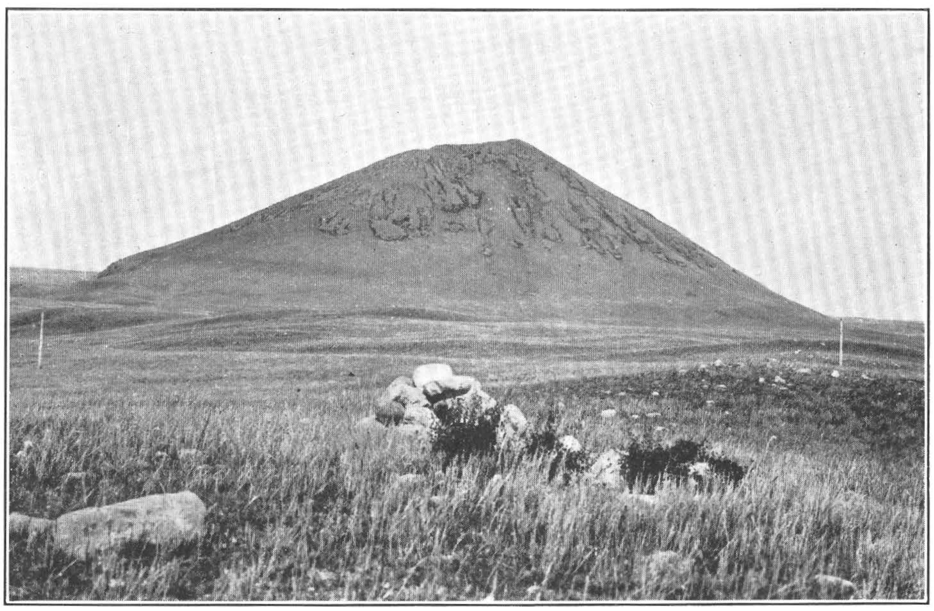


MAP OF LITTLE ROCKY MOUNTAINS, MONT., AND THEIR ENVIRONS SHOWING RELATIONS OF THE KEEWATIN ICE SHEET IN PLEISTOCENE TIME TO THE MOUNTAINS, TO THE REMNANTS OF THE HIGH GRAVELLY BENCHES AND TERRACES, AND TO THE STREAMS



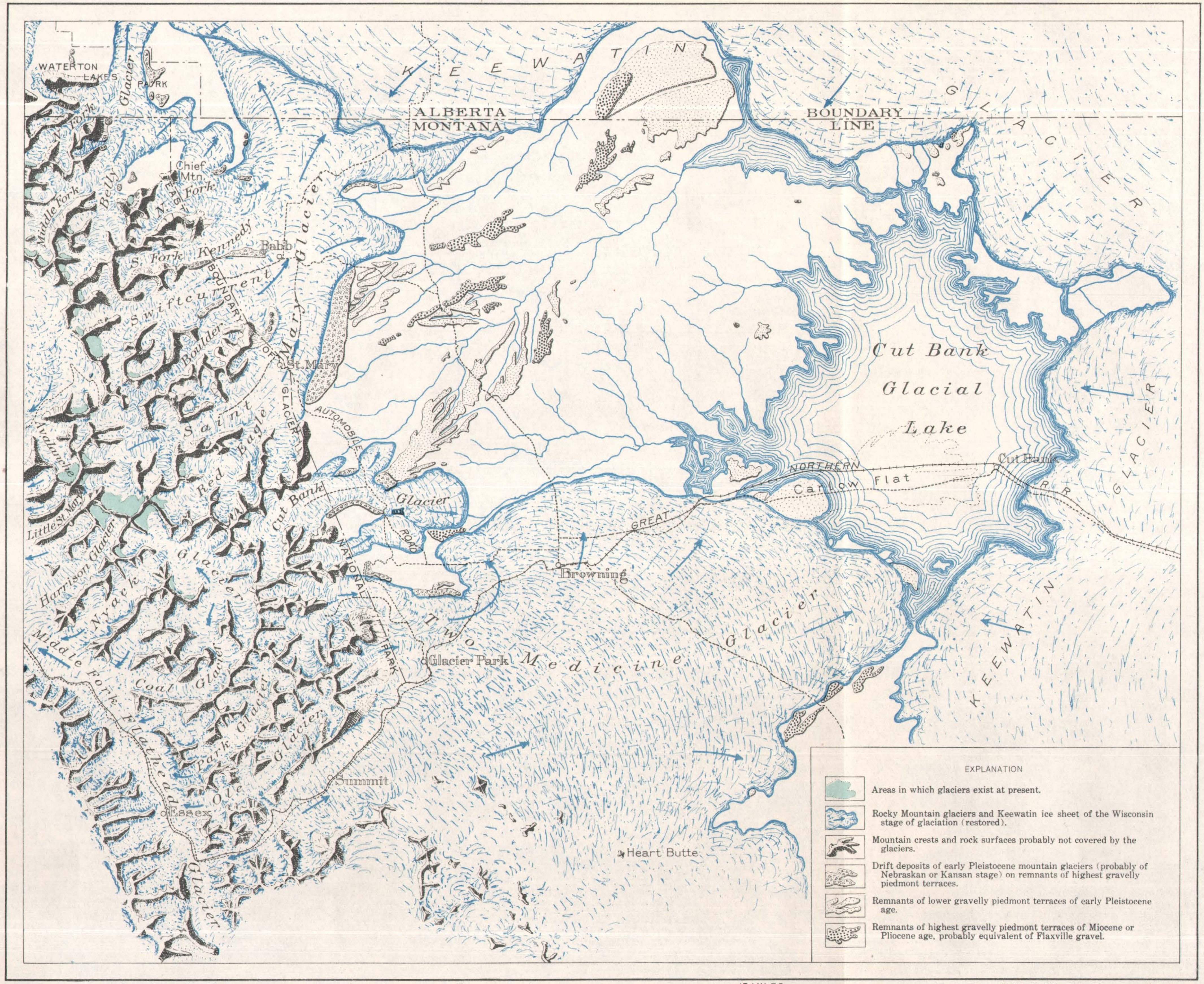
A. TWIN BUTTES, FORT BELKNAP INDIAN RESERVATION, MONT., 9 MILES NORTH OF HAYS

On the top, 850 feet above the plain, are drift pebbles showing that the buttes were overridden by the glacier.



B. EAGLE BUTTE, BEARPAW MOUNTAINS, MONT.

View looking west along top of terminal moraine of the early Wisconsin stage of the Keewatin ice sheet. The ice front reached the foot of the north (right) slope of the butte.

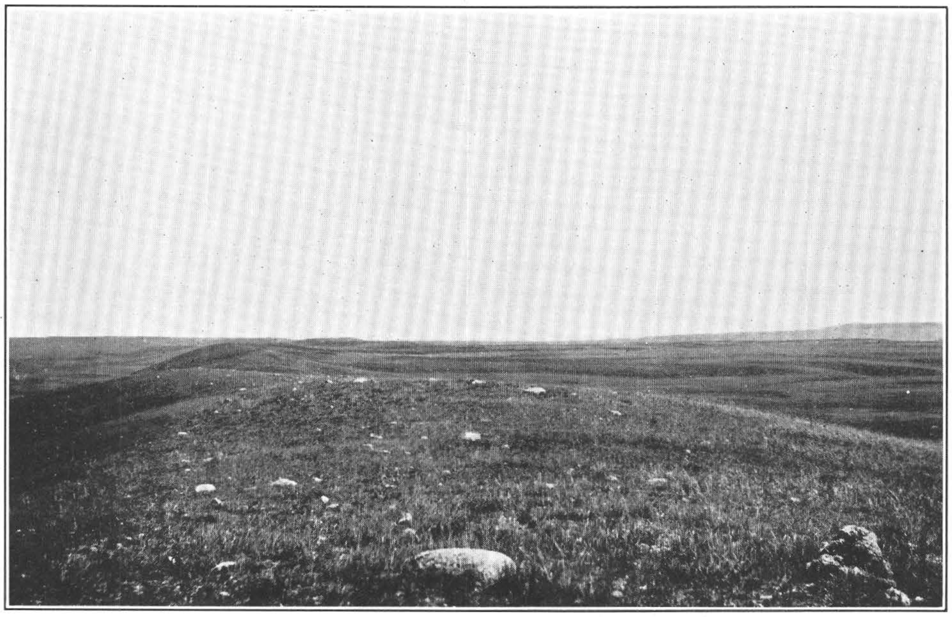


Shading by H. F. Clark, based on topographic maps. Dissected driftless plains and lowest terraces unshaded.

5 0 15 MILES

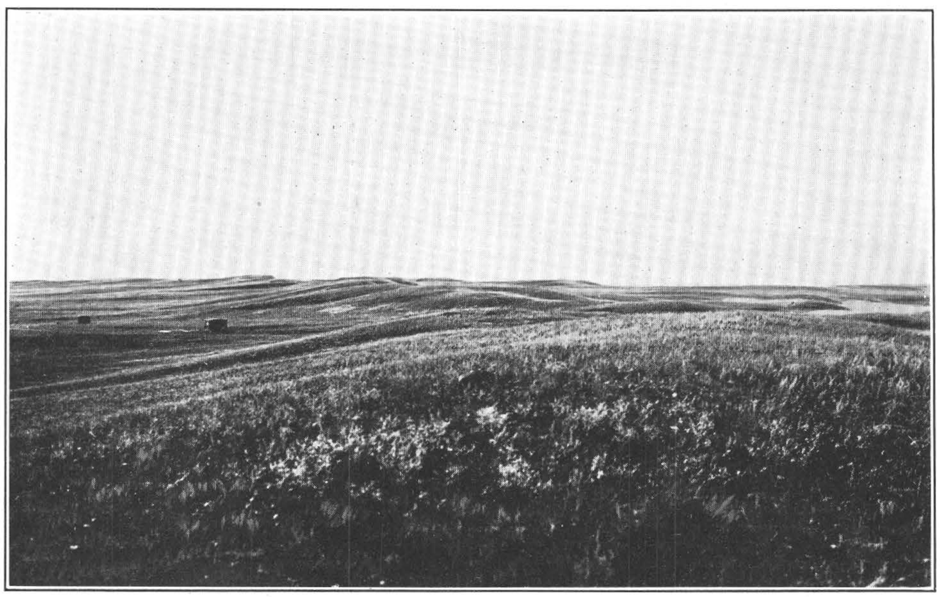
By Wm. C. Alden, Eugene Stebinger, and assistants.

EASTERN PORTION OF GLACIER NATIONAL PARK AND ITS ENVIRONS AT THE WISCONSIN STAGE OF GLACIATION



A. TERMINAL MORAINE ABOUT 25 MILES NORTH OF CUT BANK, MONT., IN SEC. 14, T. 37 N., R. 7 W.

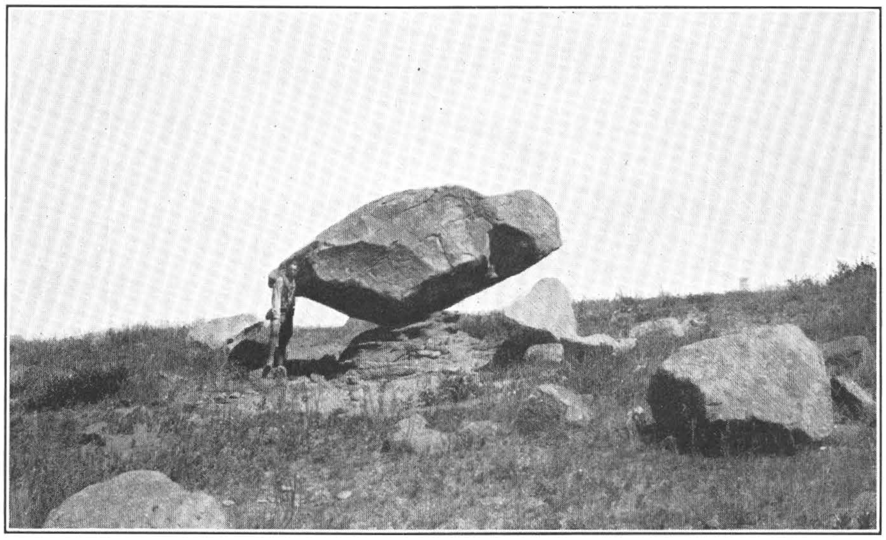
View looking east along the crest of the moraine where it lies on a gravelly bench 4,300 to 4,400 feet above sea level at the crest of the bluff south of the Milk River. Photograph by Eugene Stebinger.



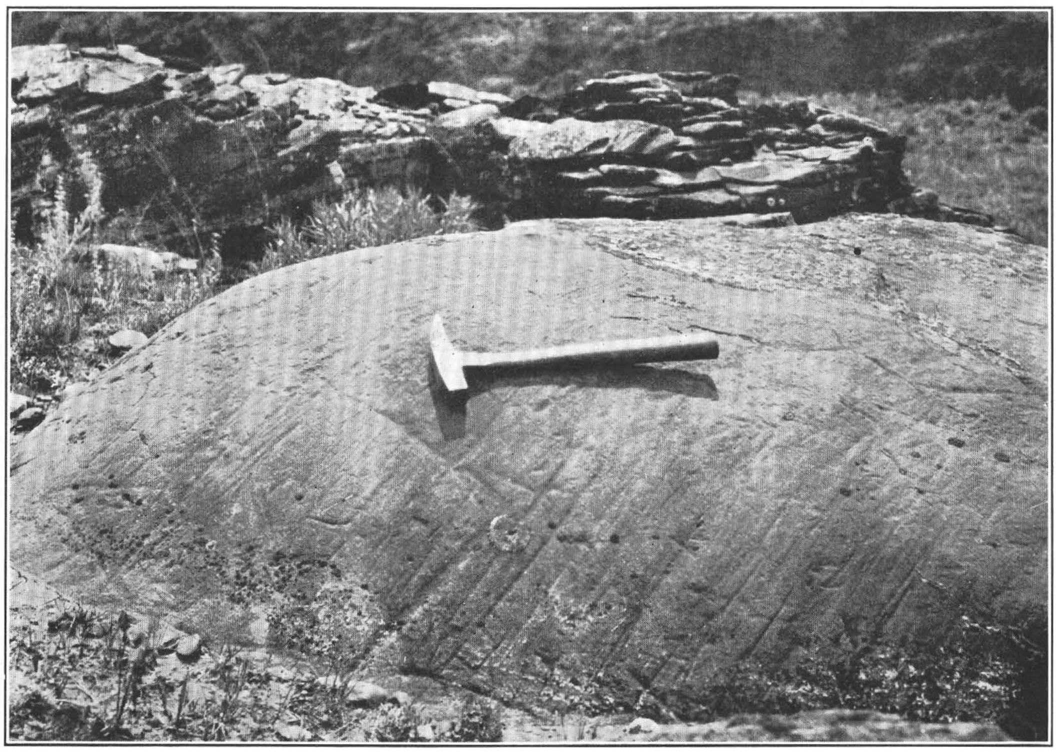
B. RECESSIONAL MORAINE NEAR MARTIN LAKE, 25 MILES NORTH OF MALTA, MONT.

View northwest along crest of moraine. The cabins are on the plain just south (outside) of the moraine.

MORAINES OF THE KEEWATIN ICE SHEET, EARLY WISCONSIN STAGE

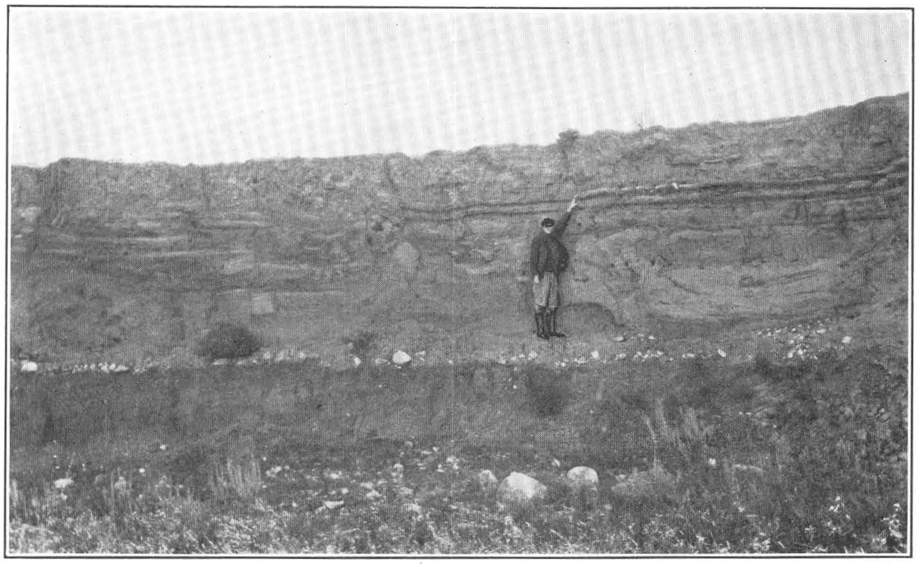


A. PERCHED BOULDER ON SNAKE BUTTE, 12 MILES SOUTH OF HARLEM, MONT.



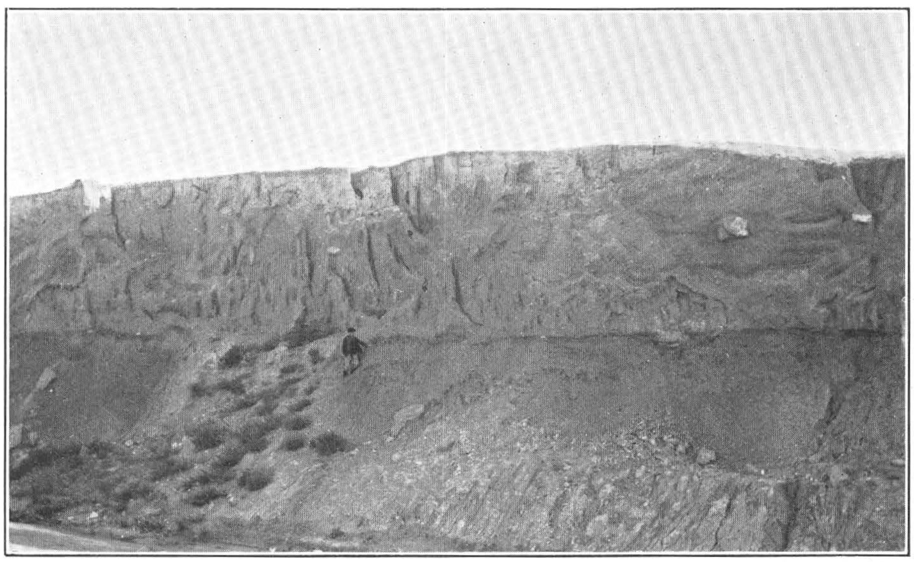
B. GLACIAL STRIAE ON LEDGE OF JUDITH RIVER SANDSTONE ON SIGNAL BUTTE, ABOUT 30 MILES NORTH OF HAVRE, MONT.

Photograph by Eugene Stebinger.



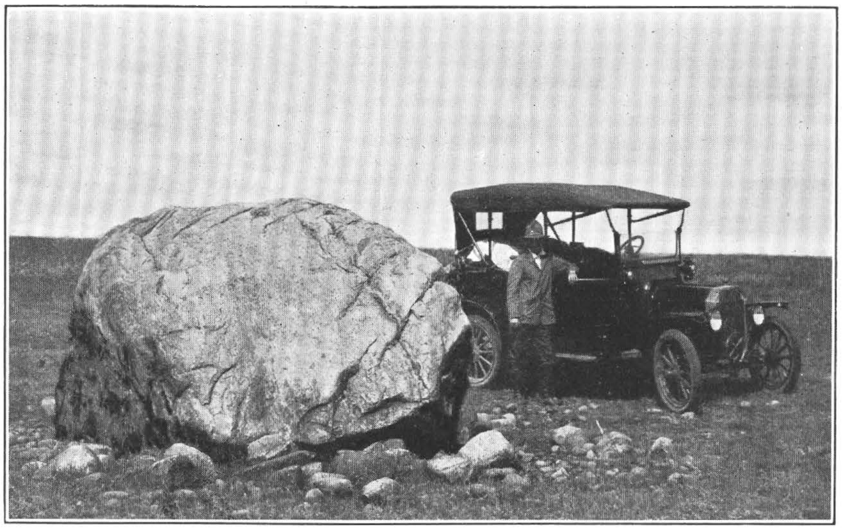
A. GLACIOLACUSTRINE DEPOSITS OVERLYING GLACIAL TILL

Top of till is at line of stones below the man's feet. Photograph by A. J. Collier.

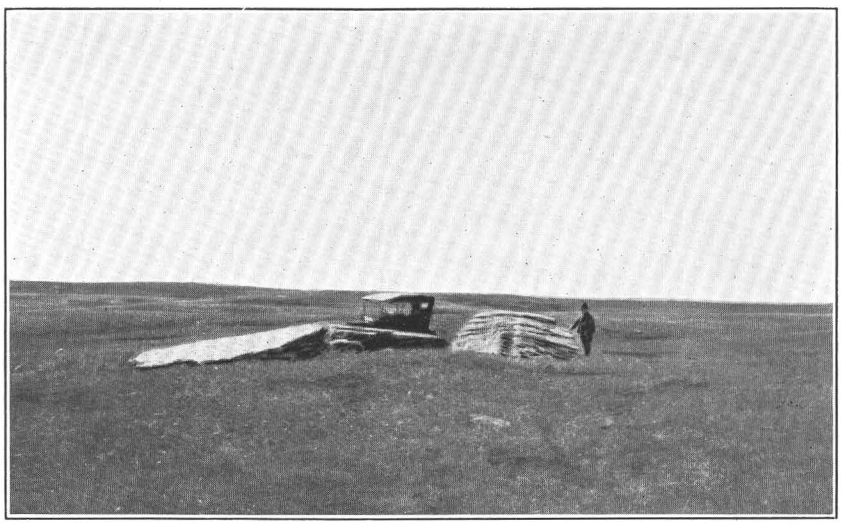


B. TILL OF KEEWATIN ICE SHEET OVERLYING JUDITH RIVER FORMATION

VIEWS ON PEOPLES CREEK IN FORT BELKNAP INDIAN RESERVATION, SEC. 20, T. 29 N., R. 25 E., 15 MILES SOUTHWEST OF DODSON, MONT.



A. BOULDER OF RED GRANITE ON UPLAND 20 MILES NORTH OF MALTA, MONT.



B. TRANSPORTED BLOCKS OF PALEOZOIC LIMESTONE ON UPLAND NORTH OF NELSON RESERVOIR, 18 MILES NORTHEAST OF MALTA, MONT.

GLACIAL BOULDERS

that some of the lower till, that of the mountain ice, is of pre-Wisconsin age is discussed above (p. 69).

Cuts exposing till of the mountain glacier were observed as far down the valley as Sloan's ranch, about 2 miles north of the international boundary, in sec. 9, T. 1 N., R. 25 W., Alberta. Some cuts expose only one of the tills, without the other, though boulders of pre-Cambrian granite from the northeast are generally scattered over the adjacent land.

Near Sloan's ranch the edge of an upturned bed of oyster shells in the Horsethief sandstone showed glacial polish in 1912 and striations trending S. 30°–50° W., toward Chief Mountain. At another point above Kimball, where the St. Mary River cuts through the folded rocks, striae were observed trending S. 55°–60° W. These are probably the product of the Keewatin ice sheet moving southwestward and are the only glacial striae that have been observed on the plains of southern Alberta and Saskatchewan by the writer or, so far as known to him, by anyone else. On Signal Butte, north of Havre, Mont., in sec. 28, T. 37 N., R. 15 W. (pl. 39 *B*), a striated ledge of sandstone was seen by Stebinger, but unfortunately this ledge had been tilted somewhat out of place, so that the exact original bearings of the southward-trending striae could not be determined.

At the sharp bend in the St. Mary River just below the mouth of Boundary Creek, in the NW. 1/4 sec. 4, T. 37 N., R. 13 W., there was exposed in 1912 about 60 feet of dull buff to gray till, containing a small percentage of pre-Cambrian crystalline pebbles from the northeast, overlying the eroded surface of friable gray sandstone. The presence of scattered granite boulders on the hills between the river and Pike Lake is probably due to berg transportation. The limit of the Keewatin drift west of the St. Mary River crosses the Canadian line in the vicinity of Boundary Creek and extends thence northwestward to the Belly River Valley. It is probable that Boundary Creek owes the peculiar direction of its course in T. 1 N., R. 26 W., Alberta, and its return southward across the boundary to its junction with the St. Mary River to the position of the Keewatin ice front. The moraine was not mapped north of the boundary by the writer, though it was examined in 1912 where it is crossed by the Belly River, about 9 miles north of the line.

There are on the Belly River deposits of till south of the terminal moraine, which include pebbles of pre-Cambrian crystalline rock from the northeast and which suggest the possible presence of pre-Wisconsin drift in the valley bottoms, as on the St. Mary River. At the terminal moraine, which is well marked by bouldery knolls, sags, and ponds, the following section was exposed:

Section of drift on Belly River

	Feet
Drift of Keewatin ice sheet: Loose dull-buff clayey till containing, besides pebbles of mountain rocks, pre-Cambrian crystalline pebbles from the northeast	20
Drift of Belly River Glacier: Very stony till in which pebbles and boulders are wholly of mountain rocks	20–30
Tertiary (?) gray sandstone	30–50

The face of the exposure was somewhat obscured, but nothing was seen which indicated long exposure of the mountain drift before it was covered by drift of the Keewatin ice.[88]

RELATIONS OF TWO MEDICINE GLACIER AND THE KEEWATIN ICE SHEET

The valleys of Two Medicine and Cut Bank Creeks had been cut down 100 to 200 feet below the lower level of the second bench represented by Carlow Flat, before the Two Medicine Glacier, heading in the mountains, and the Keewatin ice sheet approached each other at the early Wisconsin stage of glaciation. Only the narrow inner gorges and tributary coulees have been cut since the disappearance of these glaciers. Not until the line of the Great Northern Railway is reached southeast of Cut Bank by one going northward is the Keewatin drift found to be bordered by a well-marked terminal moraine. Stebinger has, however, traced the approximate limit of the Keewatin drift in a sinuous line over the hills and across the valleys with considerable care. (See pl. 1.) He found 15 to 70 feet of Keewatin pebbly clay till overlying 5 to 10 feet of mountain stream gravel exposed above the Cretaceous rocks in the sides of the gorges on lower Birch Creek and Two Medicine Creek.

From this section it appears that Two Medicine Creek had cut down its channel to a level less than 50 feet above that of its present bed before the early Wisconsin stage of glaciation—that is, about 600 feet below the nearest remnants of the high No. 1 gravel bench. This channel was then floored with 15 feet of stream gravel. When the Keewatin ice blocked the valley and formed a lake, laminated silts were deposited therein, and as the ice continued its advance it overrode the lacustrine beds for some distance and left thereon a deposit of glacial till containing many pebbles and boulders of pre-Cambrian granite from the northeast. After the ice disappeared the stream cut down again about 100 feet.

[88] Observations by the writer and Eugene Stebinger in 1912 on the drift northward to the Old Man River are described in Geol. Soc. America Bull., vol. 24, pp. 545–566, 1913.

Stebinger states in his notes of June 19, 1912, that the relations of the several deposits exposed in the east bluff on Two Medicine Creek are very clear, as seen on looking east from the southwest corner of sec. 6, T. 31 N., R. 6 W. (See fig. 16.) The section, which is about 1 mile long, is cut across a pre-Wisconsin channel of Two Medicine Creek by a bend in the present gorge of the stream.

The thicknesses given in Figure 16 are from notes on part of this section or another near by which was observed a few days previously. The surface of the gravel (B) is said to be the same as that of the fourth (from the bottom) of a set of gravel terraces developed upstream from this locality within the area covered by the Two Medicine Glacier. This terrace had been formed and the stream was cutting down to the next terrace level when interrupted by the advance of the mountain ice. In the sections in this vicinity described by him, Calhoun[89] interpreted the gravel (B) as outwash from the mountain glacier of the Wisconsin stage and, inasmuch as the gravel is overlapped by Keewatin drift, he concluded that the Keewatin ice reached its maximum extent later than the mountain glaciers and after their fronts had been melted back somewhat. He states that a few of the pebbles in the gravel are striated but that most of them have been subjected to so much water action that all trace of glaciation has been removed. From the relation of the mountain drift to the gravel terraces on Two Medicine Creek Stebinger concluded that this gravel (B) was older, and as he found no striated pebbles in it, he thought it nonglacial. Whether or not the gravel is outwash from the mountain ice of the early Wisconsin stage, the same general conclusion as to the relations of the two ice sheets is supported by other observations of both men, for Calhoun[90] found the glacial lake clay overlying drift of the mountain ice in some sections and underlying drift of the Keewatin ice in others. Stebinger states in his notes of June 19, 1912, that he found in sec. 1, T. 31 N., R. 7 W., about a mile west of the section described above and 500 feet inside the outer edge of the terminal moraine of the Two Medicine Glacier, a small mound of unmistakable continental drift and that "this must mark the west limit of advance of the Keewatin ice—that is, the ice sheets actually overlapped each other's area." He finally concludes, however, that the drift of this mound may have been dropped from floating ice, like the boulders of pre-Cambrian crystalline rocks found farther up the valley. One of these boulders, 4 feet in diameter, he found about 2½ miles northeast of Piegan, in sec. 9, T. 31 N., R. 8 W., resting on the slope beside Badger Creek at 3,895 feet above sea level. This place is 11 miles up the valley, outside the limit of the Keewatin drift and 10 miles inside the limit reached by the mountain ice. The outlet of the lake was probably southward to the Birch Creek Valley close to the front of the Keewatin ice sheet.

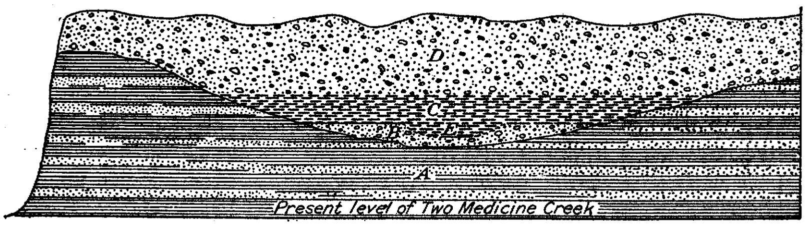


FIGURE 16.—Geologic section on Two Medicine Creek 12 miles southwest of Cut Bank, Mont. A, Cretaceous clay and sandstone of Two Medicine formation, 45 feet thick; B, nonglacial stream gravel from Rocky Mountains, with its surface 60 feet above the present stream, 15 feet thick; C, glaciolacustrine beds—laminated clay, 22 feet thick; D, dark pebbly clay till of Keewatin glacier, 50 feet thick; E, preglacial stream channel

Stebinger suggests that the Two Medicine drift was deposited first, although the time between the two invasions may have been very short. The till of both the Keewatin and Two Medicine Glaciers, which is exposed in these sections, is regarded as representing the early Wisconsin stage. There seems to be no strong reason for thinking that either one is older than this. It is possible, however, that some of this drift was deposited by the Two Medicine Glacier at the Illinoian or Iowan (?) stage. Calhoun found fine, loesslike, wind-blown material present in one section underlying the lacustrine clay where that is overlain by Keewatin till; in another place an eolian deposit overlies lacustrine clay with no till above and with mountain gravel below; in a third place an eolian deposit overlies lacustrine clay that is underlain by till of the Two Medicine Glacier.

LACUSTRINE DEPOSITS AND BOULDER TRANSPORTATION

Inasmuch as the drainage from the north side of the Little Rocky Mountains and from the Fort Belknap Indian Reservation goes mostly northeastward to the Milk River by way of Peoples Creek and its tributaries, there was much water ponded along the ice fronts in this area, both during the stages of advance and during those of retreat and in connection with both the earlier and the later ice invasions. The lacustrine deposits observed here, however, appear to belong, at least mostly, to the early Wisconsin stage of glaciation.

When the ice front lay along the northeast flank of the Judith River sandstone ridge between Warm

[89] Calhoun, F. H. H., op. cit., pp. 46–48.

[90] Calhoun used the name "Blackfoot Glacier" for the ice which is designated in this paper "Two Medicine Glacier." The change of name was proposed by the writer in Geol. Soc. America Bull., vol. 23, p. 688, 1912, because of the fact that the largest of the existing glaciers in Glacier National Park, but 10 miles from the head of Two Medicine Valley at the nearest point, bears the name "Blackfeet." The name "Two Medicine Glacier" seems to the writer better for the extinct glacier, which headed principally in valleys tributary to the Two Medicine River.

Spring and Little Warm Spring Creeks, in T. 26 N., R. 26 E., these streams were blocked, and the ponded water escaped southward through the sag in which is the reservoir on the Malta road. (See pl. 35.) Ponded water in the Lodgepole Creek Valley probably escaped westward toward Hays and thence to Section Creek (p. 100). About a mile south of the point where the Harlem-Lodgepole road crosses Lodgepole Creek the writer observed, in 1921, an exposure of 15 feet of dull-gray glacial till overlying lacustrine clay (fig. 17), the strata of which were disturbed and upturned as by the push of the glacier advancing from north to south over the bottom of the lake. Collier found similar relations in an exposure a few miles to the west on Jim Brown Creek. Numerous other exposures were seen by Collier which showed stratified lacustrine clay overlying glacial till. As the ice front melted back northward down the slope the marginal lakes either enlarged or shifted down the slope in the valleys and on top of the till. At one of the exposures on Peoples Creek in the NE. 1/4 sec. 20, T. 29 N., R. 25 E., there is about 10 feet of stratified clay overlying the glacial till. In the lower part of the clay (near the feet of the man shown in pl. 40 *A*) were found shells identified by W. H. Dall[91] as "a species of *Lymnaea* common to the northern portion of North America and named *L. vahli* by Mörch from Greenland specimens, but is common all over the northern regions from Alaska to the St. Lawrence drainage." In the upper part of this section (pl. 40 *A*, near the man's hand) were found fragments of a lower jaw with teeth and other bones, which were identified by C. W. Gilmore as from a recent bison. From these fossils it would seem that when the lower part of the stratified clay was deposited snails had come into the basin of Peoples Creek and that by the time the upper part of the clay was being laid down bisons were feeding along the streams. It is possible that the upper part of the clay here and in some of the other places is really alluvial rather than fluviatile, that the lakes had been drained, and that the streams were silting up hollows but had not yet cut their present trenchlike valleys.

Till overlying lacustrine or stream deposits was observed by V. H. Barnett on Snake Creek 9 to 10 miles west of the Fort Belknap Indian Agency, in the NW. 1/4 sec. 25, T. 32 N., R. 21 E. The following section is taken from Barnett's notes, July 20, 1908:

Section of drift on Cretaceous sandstone, Snake Creek, west of Harlem

	Feet
Glacial till; hard yellowish boulder clay with some lenses of stratified sand and gravel	15
Glacial till; hard dark-colored boulder clay with many small pebbles and few large ones	?
Stratified sand, clean, fine, and dark-colored	5
Silt, stratified	2½
Gravel, clean; some pebbles 8 inches in diameter	3
Cretaceous sandstone	15

[91] Letter of Nov. 7, 1921.

Another feature referable to water ponded or flowing along the ice front is a line of great boulders of rock such as forms the upper cliffs and top of Snake Butte, which extends southeastward from that butte across T. 30 N., R. 23 E., into T. 29 N., R. 24 E. Inasmuch as no ledges of such rock are known to occur anywhere northeast of Snake Butte, and as the general direction of glacial movement across the reservation appears to have been southerly or southwesterly, these boulders seemingly can not be referred to glacial transportation from Snake Butte. If, however, at one stage of recession of the glacial margin the ice front extended from northwest to southeast across the reservation along a line south of the Milk River, a large amount of water would probably be ponded or flowing southeastward between the ice dam and the higher land to the south and escaping thence eastward to Alkali Creek or Warm Springs Creek and so across Phillips County to the Missouri River.

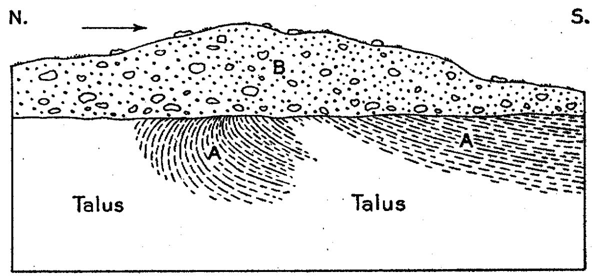


FIGURE 17.—Geologic section in the Fort Belknap Indian Reservation, on Lodgepole Creek 6 miles below Lodgepole, Mont. A, Upturned laminated clay, glaciolacustrine; B, till of Keewatin ice sheet. Arrow indicates direction of ice movement

Great masses of ice, freezing about blocks fallen from the cliffs of Snake Butte and drifting thence southeastward with the water, might transport such big boulders and drop them at the places where they now lie. That the ice front actually did halt for a time in such a position is suggested by mild morainal deposits observed at several points and described on page 110.

In this connection may be noted the occurrence of many loose blocks of shonkinite on top of Snake Butte. One of these, a boulder 15 feet long, is perched on a pedestal several feet high. (See pl. 39 *A*.) Though composed of the local rock it appears to have been carried or lifted by the moving glacier and there let down in a balanced position upon the pedestal as the ice melted away. One side of another large block seen is planed and coarsely striated by the glacial action. The rock appears to disintegrate readily after long exposure to the weather, so that most of the surfaces are roughened by etching, and there is much loose granular material from crumbling of the rock, and more has doubtless been blown away. At the highest part of the butte the surface of the rock is curiously etched by weathering, which has produced hollows from 1 to 10 feet across and from a few inches to 3 feet deep. Some are steplike, others like seats with rounded backs and sides but open toward the south. Apparently this weathering has mostly taken place since the disappearance of the ice. There are many small boulders of pre-Cambrian granite from Canada and pebbles of quartzite scattered over the top of the butte. Great gaping cracks permit entrance of snow and water, and freezing tends to disrupt the rock and break great masses off the face of the cliffs.

Other large boulders were brought into this region by the glacier from regions far to the northeast. Several large boulders of gray granite occur on Warm Spring Creek by the bridge near Brookside, in T. 27 N., R. 27 E., one of them measuring 5 by 7 by 15 feet. Others lie on the hills off to the east. Charles T. Redfield, surveyor, marked the location of a granite boulder on the plat of T. 26 N., R. 27 E., near the north line of the NE. ¼ NW. ¼ sec. 4. This boulder, which was not seen by the present writer, is stated as measuring 20 by 50 by 75 feet. If this notation is correct, it is one of the largest known glacial boulders in the United States. A boulder of red granite measuring 7 by 8 by 8 feet was seen by the writer on the smooth upland north of Little Cottonwood Creek, about 20 miles north of Malta, in T. 33 N., R 30 E. (See pl. 41 *A*.)

Three large blocks of limestone were seen on the upland 6 or 8 miles northeast of Lake Bowdoin and north of Nelson Reservoir, in T. 32 N., R. 32 E. The largest (pl. 41 *B*) measured 3 by 12 by 22 feet. No fossils were seen here, but it is probable that these are blocks of Devonian or Silurian limestone derived from ledges somewhere in the vicinity of Lake Winnipeg, whence they were carried more than 400 miles southwestward by the ice and left in their present resting place. The exposed sides of the blocks do not show the effects of glacial abrasion, yet their uneven surfaces appear not to have been much roughened by weathering. The corners have been polished by the rubbing of countless buffaloes and range cattle.

NUNATAKS AND SLOPE OF THE TOP OF THE ICE

About 20 miles east of the sandstone escarpment in western Toole County is West Butte of the Sweetgrass Hills; about 10 miles southeast of this is Middle Butte; and about 10 miles farther east, in northwestern Liberty County, is East Butte. Calhoun [92] gives the following data concerning these buttes:

Of these, West Butte is the highest, its summit being about 6,800 feet (aneroid) above sea level. The East Butte is several hundred feet lower, while Middle Butte, the smallest of the three, is but 6,000 feet in height. * * *

A careful examination of these buttes showed conclusively that they were not covered by the ice sheet but that they stood as great nunataks about 2,000 feet above its general level. Not only were they not covered by the ice of the Keewatin ice sheet, but there is no evidence that they were locally glaciated. The ice from the northeast, when it reached them, was near the end of its long journey and was a depositing rather than an active body. On the west, north, and east sides of West Butte a well-defined terminal moraine is banked against the slope. On the south side there is no such terminal moraine, and for some distance south the country is driftless. The ice, divided by the butte, did not come together till it reached a point about 2 miles south of its foot. The moraines left by these two ice edges as they circled the butte and pushed south over the plain are well defined. The moraine on the west slope of the butte is 1,200 feet above the plain; along Milk River on the north side it is 1,500 feet, and on the southeast side it is 1,300 feet. This, then, would make the average thickness of the ice about 25 miles from its edge. In this distance the slope of the upper surface of the ice averaged about 50 feet per mile. On the southeast side of West Butte the slope of the ice, as determined by the slope of the moraine, was 70 feet per mile. Thus it is seen that along the edge of the ice the slope was low, due in great measure to the level plain over which the ice traveled.

Weather conditions were not favorable for accurate barometric readings when the present writer visited East and West Buttes in 1920. Such readings as were made, however, indicate that the moraine near the southwest flank of West Butte is about 4,100 feet (barometric) above sea level. The height of the surface of the ice was thus not much different here from what it was at the head of the reentrant in its outer margin on the sandstone escarpment (4,200 feet), in sec. 1, T. 35 N., R. 4 W., about 25 miles away in a direction somewhat south of west. The moraine on the eastern flank rises northward from 4,470 feet at a point east of the coal mine to 4,700 feet (barometric). Some drift boulders were seen at 4,800 feet (barometric), but the upper limit was not determined. It seems probable that ice passing the east flank of West Butte moved southwestward to the limit of glaciation on or near Two Medicine Creek south of Cut Bank, 55 miles from West Butte, where the altitude is about 3,600 feet. The average slope of the surface of the ice along this line must, therefore, have been about 22 feet to the mile. At the north flank of East Butte the moraine is developed near the county road on the bench below Black Butte at about 4,350 feet (barometric). No drift was seen on top of Black Butte (5,050 feet, barometric) or on its slope. If these barometric determinations are anywhere near correct, the ice did not crowd up on East Butte as high as on West Butte. Ice passing East Butte probably reached eastern Teton County, 80 miles away, where the moraine front has an altitude of about 3,700 feet. (See pl. 1.) It would seem, therefore, that the slope of the surface of the ice along this line, which is near the axis of the lobe, could not have been more than 10 feet to the mile.

GLACIAL LAKE CUT BANK

The front of the Keewatin ice sheet, when standing in the position described above, completely blocked

[92] Calhoun, F. H. H., op. cit., pp. 11, 28.

the valley of Cut Bank Creek so that for 20 miles the ice dam was bordered by the water of an extensive lake (pl. 37), which has been designated glacial Lake Cut Bank.[93]

Granitic pebbles and boulders such as those found by the writer on top of the hill southeast of Cut Bank are present at several places in the basin farther north and west at altitudes below 4,000 feet. These were dropped from icebergs floating on this lake. Laminated silt was also observed at several places by Stebinger. (See pl. 25 *B*.) The silt apparently underlies the flatter parts of the basin, as much as 30 feet being exposed by some of the coulees. Stratified sand and gravel are also seen in places. The actual extent of the lacustrine deposits, however, has not been determined. Nowhere have any definite shore lines been seen. The area mapped as covered by the lake includes that lying below the 3,900-foot contour, together with some of the slopes between 3,900 and 4,000 feet. Carlow Flat was also probably submerged part of the time as far west as the canal south of Seville. Pebbles of pre-Cambrian granite from Canada were observed on this flat about 4 miles west of Cut Bank at 3,915 feet above sea level. About 8 miles southwest of Cut Bank granite pebbles were found at 4,050 feet. This may mark the maximum and first level of the water. The outlet of the lake was southward along the ice front near this place. Later the water fell to 3,900 feet and flowed through the sag occupied by the ponds in sec. 21, T. 32 N., R. 6 W. The present inner gorge of Cut Bank Creek was cut after this lake was drained. This lake not only received the drainage from the adjacent land area but also from all the north front of the Two Medicine Glacier for a distance of 50 miles from the Squaw Buttes, southwest of Cut Bank, westward to the mountains, the drainage from the Cut Bank Glacier, and water from the South Fork of the Milk River. Water from the great St. Mary Glacier and from both the mountain glaciers and the Keewatin ice sheet for an unknown distance north of the international boundary was diverted to the South Fork of the Milk River and thence to glacial Lake Cut Bank by way of an abandoned channel in the southern part of T. 37 N., R. 7 W., which leads from the Milk River northeast of Landslide Butte to the head of Rocky Coulee.

The lamination in such deposits as are shown in Plate 25 *B* is due to an alternation of very fine grained sediments with coarser-grained silt. It is believed that the coarser material is that which was washed into the lake during spring and summer storms and that the denser layers consist of the finest sediment which remained in suspension, to be precipitated only during the winter, when freezing so covered the lakes with ice that no more coarse material was washed in and the waters were not disturbed by waves or currents.

If it were assumed that each layer of the laminated clay deposited in this lake is a varve, representing one season's deposition, careful study of the clay might make it possible to compute a minimum number of years that the lake was held in by the dam of glacial ice, just as the age of a tree is determined by counting the number of annual rings of growth.

RECESSIONAL MORAINES AND DRAINAGE OUTLETS

Within (north of) the terminal moraine described above (pp. 96–103) are certain morainal tracts or belts, some of them well marked, others patchy and very poorly marked, which appear to represent positions of halt (or readvance and halt) of the glacial margin during the general progress of final deglaciation of the plains of Montana. These have been noted by the writer at various times in making crisscross traverses of the area, and were they traced in detail they might be found more continuous than is now known. Certain hypothetical lines of correlation might be drawn on the map to show successive probable positions of the retreating ice front. The general relations, together with the distribution of these faint morainal deposits and the shifting of drainage lines, indicate that deglaciation was accomplished by progressive melting back of the glacial front from southwest to northeast. As the ice front receded down the general slope south of the Milk River Valley drainage lines shifted, and in places great trenchlike abandoned watercourses mark temporary positions of the shifting streams. A remarkable series of such ancient watercourses is found in Alberta and Saskatchewan, Canada. Many of these, called coulees, are not now traversed throughout their length even by intermittent streams. They cut across divides between the present drainage lines, and some are occupied in part by chains of elongated shallow lakes or marshes.[93a] Similar features are found in Montana, but not all have been mapped. One such trench near the outer limit of the ice in Pondera and Teton Counties leads from the Pondera Basin, southwest of Conrad, to Muddy Creek, northwest of Collins.

A second such drainage course leads southward across the international boundary at Coutts, Alberta. This is followed by the Sweetgrass branch of the Great Northern Railway to Virden, Mont., by the main line to Shelby, and by the Great Falls branch from Shelby across the Marias-Teton divide between Conrad and Brady. By this course waters from far to the north reached the Teton and Missouri Rivers as soon as the Teton Valley was cleared of ice. Near and south of

[93] Alden, W. C., Glaciers of Glacier National Park, pl. opp. p. 32, U. S. Dept. Interior, 1914.

[93a] Williams, M. Y., The physiography of the southwestern plains of Canada: Royal Soc. Canada Trans., vol. 23, sec. 4, pp. 71–76, 1929.

Shelby the trench is a broad flat-bottomed valley with abrupt side slopes. Stebinger found two other trenches cut across the divide between Marias River and the Dry Fork, north of Conrad. The Wittley trench between Conrad and Brady is 100 to 125 feet deep. Another such outlet 100 to 150 feet deep crosses the divide between Pondera Creek and the Teton River about 20 miles east of Brady, in T. 26 N., R. 2 E. This may be the correlative of a similar trench, Dead Indian Coulee, 130 feet deep, which Stebinger noted as cut across the divide between Marias River and Pondera Creek in T. 29 N., R. 2 E. Yet another outlet was crossed east of Egly, in or near the southeastern part of T. 27 N., R. 6 E.

Some features suggestive of a recessional moraine are belts of low bouldery drift swells north of Shelby and east of the Sweetgrass branch of the Great Northern Railway, in Ts. 34–36 N., R. 2 W. Similar belts were also seen between Collins and Brady and about 15 miles east of Brady. A belt of gravel knolls was also observed by L. J. Pepperberg's party [94] north of Lonesome Lake Coulee, southwest of Boxelder. This belt extends northeastward to the flat between Sandy Creek and the Great Northern Railway and may be correlative with a similar belt crossed by the writer in 1921 south of Boxelder. This belt might perhaps be traced northeastward to the outer moraine east of Square Butte.

The abrupt change in direction of Marias River from an easterly course in southern Liberty and Hill Counties to a southerly course in Chouteau County suggests that the latter course is the result of permanent diversion when the ice front had receded to a position somewhere to the northeast. The presence of a buried former channel of Marias River extending eastward from the vicinity of the sharp bend through T. 29 N., Rs. 9–13 E., toward the buried former valley of the Missouri River southwest of Boxelder has not been demonstrated, but the probability of its existence seems very strong. Northeast of the bend, near the middle of T. 29 N., R. 9 E., Black Coulee is for some distance cut wholly in drift to depths of 30 to 80 feet. Farther south the coulee is cut into black shale. East of Black Coulee a broad nearly flat plain slopes eastward toward Boxelder between gently sloping higher land on the north and south. (See Lonesome and Boxelder topographic maps.)

Pepperberg's and Barnett's field maps (1908) show no exposures of sandstone or shale beneath the glacial drift between Lonesome Lake Coulee on the south, in secs. 19 and 20, T. 29 N., R. 13 E., and Barneys Coulee, 5 miles farther north, in sec. 30, T. 30 N., R. 13 E., and it seems probable that through this interval the ancient Marias joined the contemporary Missouri River. The present gorge of Marias River, for some distance above and below the bend, was cut deep and narrow into the Colorado shale as the master stream, the Missouri River, reexcavated its gorge after the disappearance of the ice. Farther west up Marias River the valley is broader, and remnants of benches observed at certain points may represent the bottom of an older and shallower valley which drained eastward toward Boxelder. That the present southerly lower course of Marias River is due to glacial diversion is also indicated by the fact that sandstone-capped buttes, the so-called Goose Mountains, which are remnants of a high old divide, are but a few miles west of this southward-trending gorge. The tops of these buttes are 500 or 600 feet higher than the broad plain east of the bend of Marias River. Stebinger recorded in his field notes having observed thicknesses of 50 to 175 feet of glacial till exposed in bluffs along Marias River in what is now southeastern Toole County.

[94] Field maps, 1908.

RECESSIONAL MORAINES IN HILL, BLAINE, AND PHILLIPS COUNTIES, MONTANA

The next line along which the retreating ice front halted appears to be east of Sage Creek and along or near the Milk River Valley, and to this may perhaps be due the parallelism of the two streams west of Sandy Creek. Traces of morainal topography were noted by the writer north of Gildford, in T. 33 N., R. 11 E., and in 1915 W. P. Woodring [95] traced a well-defined morainal belt east of Sage Creek for 12 miles in a northwesterly direction in Ts. 35 and 36 N., R. 10 E.

The glacial till east and west of the Milk River was found by Stebinger's party to range generally from a few feet to 150 feet in thickness, but in many places, especially near the international boundary, 100 to 150 feet was seen. A gravelly drift ridge which may belong to the same morainal belt was noted by Barnett in 1908 about 6 miles northeast of Kremlin, and with this is perhaps to be associated a peculiar feature, Chain of Lakes Coulee, shown on the Kremlin topographic map. Examination of this map and that of the Assinniboine quadrangle, on the east, shows that the elongated depression in which lies the Chain of Lakes cuts across a detour made by the present course of the Milk River and is more nearly on a median line between the divides on each side than that part of the present stream to the east. The relations give rise to the suggestion that the Chain of Lakes lies in a partly filled pre-Wisconsin (or preglacial) valley of the Milk River.

Farther south and east on the same general correlation line is the thick drift filling of the old Missouri Valley south and east of Havre. Data are given elsewhere (p. 67) indicating the depth of this drift

[95] Unpublished field maps and notes of Eugene Stebinger's party, September, 1908.

filling. Extending eastward from a point about 3 miles east of Havre there is a tract covering more than 20 square miles on the north side of the river which is evidently a part of the same deposit. Pepperberg's and Barnett's field maps (1908) show extensive belts of "kames" and some gravelly ridges designated "eskers." Some of these features seem likely to be recessional moraine deposits, but too few of them have been seen by the present writer to warrant more than the suggestion. Some of them may mark a slightly later stage in the glacial recession, when the glacial front had been melted back north of the valley. Such are a belt of gravel knolls and ridges extending westward on the south side of Coal Coulee for several miles from a point about 6 miles north of Toledo; a belt of small hills noted in 1915 by J. D. Sears near Thibedeau Lake, together, perhaps, with numerous ponds and other features to the northwest and southeast; gravelly hills 2 miles north of Chinook; and a narrow morainelike ridge cut through by Deadhorse Coulee about 7 or 8 miles farther north, in secs. 1 and 12, T. 34 N., R. 19 E.

The uneven surface of the bench that borders the south side of the Milk River Valley from a point 2 miles west of Lohman (formerly Yantic) eastward to the Fort Belknap Indian Agency south of Harlem (see Yantic, Chinook, and Harlem or Zurich and Cherry Ridge topographic maps) suggests morainal deposits formed along the glacial front while the river channel was occupied by ice. The peculiar course followed by the Milk River near Chinook, the course of Threemile Coulee, and the presence of a sag leading from Sixmile Coulee 8 to 10 miles eastward to Snake Creek south of a low belt of hills all suggest the presence for a while along this belt of an ice dam that prevented the drainage from passing directly to the broad valley to the north. A belt of small knolls and ridges in the midst of the broad valley flat between Chinook and Harlem may represent a brief stand of the ice front after the southern part of the flat was freed from ice and occupied by border drainage. The presence of an ice dam along such a line would explain why the river cut through the ridge southeast of Chinook instead of flowing directly eastward along the line followed by the Great Northern Railway.

East of the Fort Belknap Indian Agency morainal deposits border the south side of the valley for several miles. They are best defined where a gravelly knolled ridge forms the retaining barrier on the north side of the irrigation reservoir in T. 31 N., R. 24 E. A line of low swells rising above the flat to the east may represent the continuation of the morainal belt. A somewhat earlier and more southerly line was found extending eastward in T. 29 N., Phillips County, from the vicinity of Peoples Creek to the Malta-Zortman road. This is marked by gravelly knolls and numerous sags and ponds. It probably joins the outer line of morainal deposits in the hilly belts south of Malta, described above (p. 99).

Two of the best-developed moraines of the Keewatin ice sheet in Montana are on the upland west of Whitewater Creek, in the northwestern part of Phillips County and the northeastern part of Blaine County. Parts of both of these moraines are shown on the Cherry Ridge topographic map. On the plains to the south and west the advancing glaciers found little but fine material, mostly clay, from the Cretaceous shales, with some sand from the friable sandstones. With this were mixed some pebbles and boulders from more distant sources. Moreover, at most places the ice front was bordered either by ponded waters in which only the finest silts could be spread out, or by great streams of diverted waters which swept away most of the fine material and rafted away many of the larger boulders on floating icebergs, leaving little that could be piled up in the form of morainal ridges and kames. The stronger development of moraines on the upland north of the Milk River, on the contrary, may have been the result of two factors in contrast with those noted above. (1) The glacier, in advancing across the upland, found an abundance of coarse gravel (the Flaxville gravel), which was carried forward and dumped with many crystalline boulders at the melting ice front, forming a wilderness of morainal knolls and ridges. (2) The ice front here was bordered neither by a glacial lake nor by a great river. The drainage, especially from the outermost of these two moraines, flowed directly away from the ice front to the Milk River Valley in the form of numerous small streams. Doubtless some of the fine material was swept away, but most of the coarse gravel and the boulders were left to form the moraine. The topographic map shows some of the many branching coulees which head at the more southerly of the two moraines. This moraine is best developed between 12 and 18 miles north of Harlem, Savoy, Coburg, and Dodson. It extends in a northwesterly direction as a belt about 4 miles wide, thickly set with bouldery knolls and ridges of gravelly drift interset with a multitude of sags and elongated hollows, many of which contain ponds or marshes, except in the dry seasons. North of Harlem and Savoy the moraine is laid at 3,100 to 3,300 feet above sea level along the southern border of the upland plain described above (p. 18) as underlain by Flaxville gravel. At 12 miles north of Harlem the remnant of an old gravel-capped divide begins to rise (on Judith River sandstone) above the plain to the northeast and extends thence with much dissected western slope and crest in a northerly direction as Cherrypatch Ridge to and across the international boundary in R. 21 E. As this ridge rises the moraine curves northward and is not so well defined. One feature developed in connection with the formation of this moraine is about 8 miles west of Turner. From a low altitude south of Woody Island Coulee, in the northeastern part of T. 36 N., R. 24 E., there extends in a southerly direction a line of small hills or ridges for a distance of 8 or 9 miles. This line curves gradually toward the southwest and passes east of Twete toward the moraine described above. The trend of this line of hills, as shown on the Cherry Ridge topographic map, is nearly normal to the moraine, and this and its contours suggest that it is an esker. Where examined, however, it is seen to be a succession of knolls rather than a sinuous ridge. It resembles a moraine or a belt of kames rather than an esker. The crests of some of the knolls are covered with abundant crystalline boulders, mostly gray granite. The southeasterly extension of the moraine on the dissected upland north of Malta has not been mapped. It seems probable, however, that when this moraine was formed the Milk River Valley northeast of Malta was not yet cleared of ice. Small, sharp, bouldery hills below the west bluff in the valley 12 miles northeast of Malta may perhaps be morainal, but on the other hand they may be shale hills sprinkled with boulders. They were not carefully examined.

The second of the two well-marked moraines crosses the international boundary and enters northeastern Blaine County in T. 37 N., Rs. 23 and 24 E., as shown on the Cherry Ridge topographic map. Where crossed by the writer in 1920 north of Turner, in T. 37 N., R. 22 E., the moraine is nearly 4 miles wide, very rough, and marked by bouldery hills and hollows. For a distance of nearly 30 miles in a southeasterly direction the moraine is bordered on the south by Woody Island Coulee. Where crossed north of Turner this valley is 100 feet deep and nearly a mile wide, cut in the flat gravel plain. Apparently the ice front here was bordered by good-sized streams, but the coarse morainal material was not washed away. At 11 miles east of Turner, in the southeastern part of T. 36 N., R. 27 E., the valley bends sharply to the south and the drainage enters a deep gorge leading first south and then southeast along Cottonwood Creek to the Milk River below Malta. The relations near and west of Horseshoe Lake suggest that the drainage was diverted as a result of the position and trend of the glacial margin and of the moraine. North of Horseshoe Lake and for some distance eastward the moraine is about 6 miles wide. Through most of its southeasterly course across T. 35 N., Rs. 29 and 30 E., the south front of the moraine is particularly well defined, especially on the flat upland plain. (See pl. 38 *B*.) The basins of Horseshoe Lake and Martin Lake appear to be due to blocking of a former valley by the morainal deposit. Just at the eastern edge of the upland the sharp frontal ridge of the moraine swings abruptly southward and drops down the slope, and the moraine is lost in the hilly eroded tract between Whitewater and Martin Creeks. The topographic relations and the presence of patches of morainal knolls farther south indicate that the ice front at this stage extended in a southerly direction along the hilly belt west of Whitewater Creek to the morainal hills near the foot of Nelson Reservoir, in T. 32 N., R. 34 E. East of Nelson Reservoir, in secs. 19, 20, and 28, T. 32 N., R. 33 E., the road passes along the north side of a well-marked narrow moraine which separates the flat on the north from the flood plain of Beaver Creek on the south. The irrigation canal is excavated in the south slope of this moraine.

STREAM DIVERSION NEAR LAKE BOWDOIN

In the relations of the ice front to the valleys at the several stages of recession described above is probably to be found an explanation of the diversion of the Milk River from the old Missouri Valley east of Malta. The Missouri River is thought originally to have flowed eastward through the Lake Bowdoin sag and to have been joined by the Musselshell River flowing from the south in the Beaver Creek Valley. (See fig. 18, A.) Just what was accomplished by the Illinoian or Iowan (?) ice sheet in the way of stream diversion in this locality can not now be determined. Probably Cottonwood and Little Cottonwood Creeks originally flowed southeastward to the river by way of the sag in which is now Nelson Reservoir (the trough in which are shown Lone Tree Lake and Mud Lake on the Bowdoin topographic map), inasmuch as this sag heads westward at the east side of the Milk River Valley, where it is cut off and left hanging well up in the slope. These creeks may have been turned southward by the Illinoian or Iowan (?) ice to join the river near Malta.

If the early Wisconsin ice sheet deployed to the limit described above (p. 99), it pressed against the north slope of the Larb Hills and reversed the flow in the Beaver Creek Valley, sending the stream southward as the ice lay across the hills south of Malta (fig. 18, B, A'–A–A). At this time also a stream was probably flowing southward along the valley of Larb Creek, a remarkable valley cutting directly through the hills to the Timber Creek Valley, which drains southward to the Missouri River. (See Saco topographic map.) From the outer position (A'–A) the glacial front was melted back to positions A''–A''–A and A'''–A'''–A''–A as indicated by morainal deposits south and east of Malta. When the ice front receded to the moraine that is so well marked north of Harlem it probably also retreated to the upland north of Malta and to the belt of morainal knolls north and east of Lake Bowdoin (fig. 12, B, B–B–B) while yet holding the

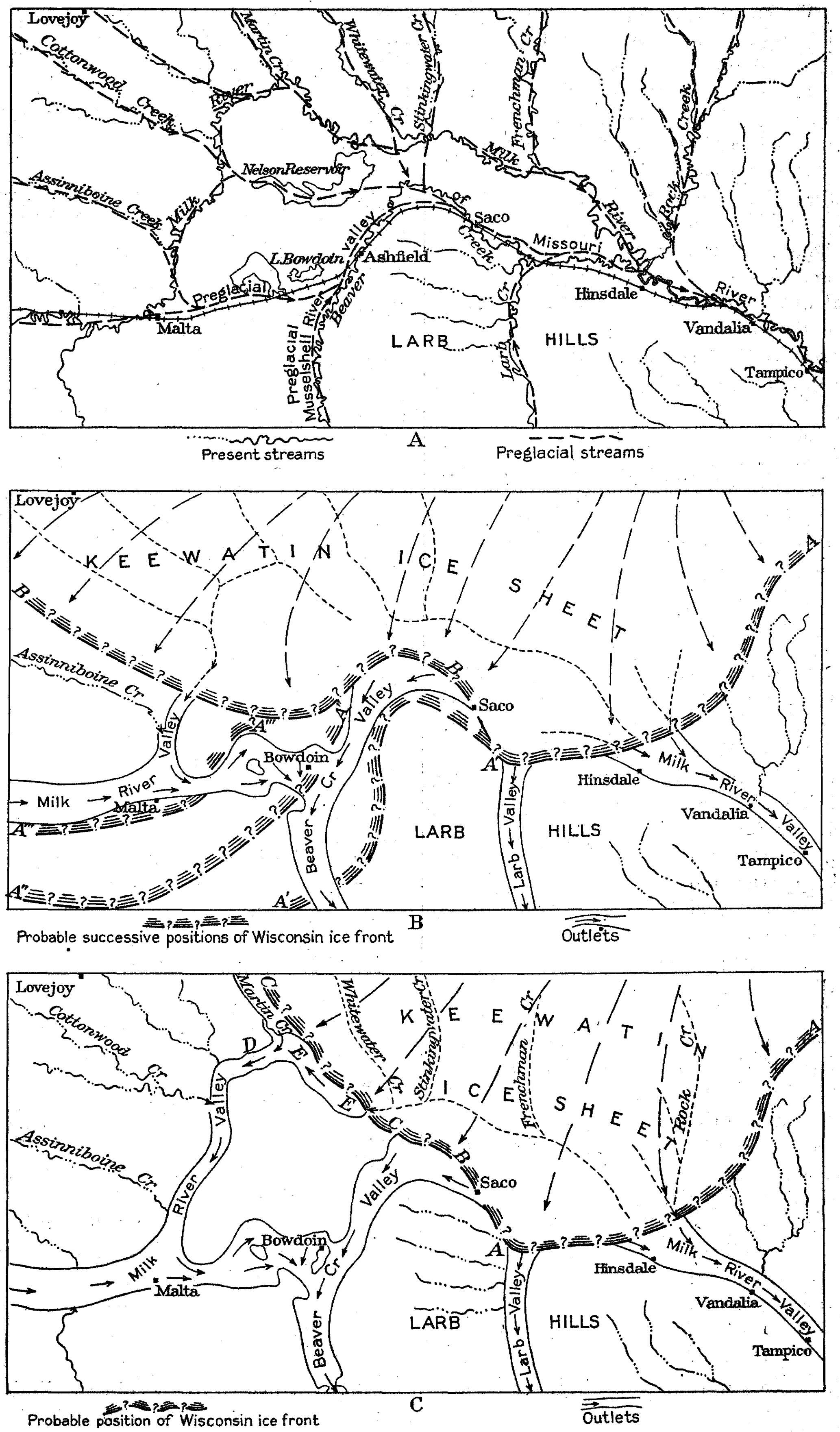


FIGURE 18.—Stream diversions east of Malta, Mont. A, Probable relation of preglacial streams (dashed) to the present stream valleys; B, probable relation of outlets of glacial waters from the front of the Keewatin ice sheet, Wisconsin stage of glaciation, at its most advanced position (*A′–A–A*) and at successive later positions (*A″–A″–A–A*, *A‴–A‴–A–A*, and *B–B–B–A–A*); C, probable relation of outlets of glacial waters just preceding the opening of the present courses of the streams by further melting of the ice. (See text for additional explanation)

position *A–A*. Water from the region west of Malta and from the ice front west of Saco would then continue flowing to and southward along the Beaver Creek Valley. If the ice front receded to the line *C–C–B* (fig. 18, C) while yet holding the position *A–A*—that is, pressed against the slopes of the uplands on the south and east—the southwestward flow to Malta and thence east through the Lake Bowdoin sag to the Beaver Valley would be increased by waters from Woody Island Coulee, by way of Cottonwood Creek Valley, and this would be joined through a col at *D* by glacial waters from the Martin Creek Valley and from the southeastward-trending part of the Milk River Valley (reversed) (fig. 18, C, *E–E*), which was probably the original valley of Martin Creek. Whitewater Creek probably originally joined the Missouri River through the broad sag (Fig. 18, A) 7 miles northwest of Saco. When the ice finally left this sag it was blocked by a morainal ridge. Whitewater Creek may also have been diverted westward around by Malta when the ice front receded east of its southeastward-trending valley, and so also in turn may Stinking Water Creek when its valley was cleared. In this way the valley now followed by the Milk River below Malta may have been deepened down to the level of the low divide south of Lake Bowdoin by water flowing toward Malta. Frenchman Creek probably previously followed its present course to the main stream east of Saco. When all these valleys were finally cleared of ice there was thus ready for the Milk River a valley along its present course northeast of Malta which was fully as deep as the sag south of Lake Bowdoin. As the ice front receded strong flows came from the north, first through the valley of Whitewater Creek and then by way of Frenchman Creek, and these reached the Missouri River below Nashua. As a consequence southward flow through the Beaver Valley ceased, and the Lake Bowdoin sag was abandoned.

There is a great morainal tract covering more than a township south of the international boundary between the east and north forks of Whitewater Creek. Collier [96] states that morainal features were observed by his party farther south, on the east side of this creek. These may mark the next position of halt after the ice front receded from the moraine at Horseshoe Lake. The relations north of the boundary are not definitely known, though the writer made north-south traverses on four routes south of the Cypress Hills. It is probable, however, that by the time the Whitewater Creek Valley was cleared of ice the glacial margin had receded to the east end of the Cypress Hills Plateau and that glacial waters were flowing through the gap now traversed by the Canadian Pacific Railway northeast of East End village, thence westward up the Frenchman Creek Valley and through the sag occupied by Cypress Lake and across to the Battle Creek Valley, by which it would reach the Milk River at Chinook.

[96] Personal communication.

RECESSIONAL MORAINES IN THE NORTHEASTERN COUNTIES OF MONTANA

By the time the basins of Frenchman Creek and Rock Creek were wholly cleared of ice the glacial margin must have been receding northeastward across the upland plains of northeastern Valley County and Daniels and Roosevelt Counties to or beyond the Poplar River Valley. On the upland east of the Poplar River there is a well-marked belt of terminal moraine which crosses the south line of Daniels County. Northwest of this, on the upland between the main and west forks of the Poplar River, is a mild morainal belt with a northwesterly trend. It is not well marked, however, elsewhere, though at several places along this divide as far northwest as the highland south of Wood Mountain post office, in T. 4 N., R. 1 W., Willow Bunch district, Saskatchewan, moraine-like knolled tracts were observed by the writer in 1916 and 1920.

A bit of a moraine also borders a high gravel-covered upland 10 to 15 miles north of Scobey and extends across the international boundary between the middle and east forks of the Poplar River. A well-marked morainal tract within a few miles of the international boundary northeast of Whitetail may perhaps be correlated with the later Wisconsin moraine east of the Big Muddy Valley. When the ice front stood here the drainage went westward from the head of the Beaver Creek Valley through a pass at the boundary nearly 200 feet deep and thence to the Poplar River.

It will be evident to the reader of the foregoing descriptions of morainal deposits that the correlations suggested from the data in hand and presented to show the successive stages of recession of the front of the melting early Wisconsin glacier can not be regarded as established. The most that can be hoped is to systematize such information as is available and present an outline to be filled in or revised from later observations. To the writer it seems fairly certain that the ice front receded from the plains of Montana not directly northward across the whole area but from southwest to northeast toward a center of dispersion west of Hudson Bay. At the next stage of melting beyond those presented above the ice front probably receded northeastward within the limits of the later Wisconsin invasion. How far the ice was melted back before it readvanced to the great moraine on the Coteau du Missouri in North Dakota is unknown.

ROCKY MOUNTAIN GLACIERS OF WISCONSIN STAGE

GENERAL RELATIONS

It is not intended to present in this paper a full discussion of the phenomena of the Pleistocene glaciers of the Rocky Mountains in Montana. A description of the deposits of the glaciers that extended out nearly to or beyond the eastern front of the mountains, beginning at the north with the Belly River Valley in southern Alberta, is given in order to show the conditions on the plains. Since the time the glacial deposits as far south as the Sun River were described by Calhoun,[97] they have been mapped somewhat more in detail, partly by the writer but principally by Eugene Stebinger, to whose field maps and notes the writer is indebted.

The continental ice sheet that formed the terminal moraine in southern Alberta and in Glacier, Toole, Pondera, and Teton Counties, Mont., is regarded as that of the early Wisconsin stage of glaciation. As was first shown by Calhoun, this Keewatin ice reached its maximum extension in this part some time after the mountain glaciers began to melt back, and it laid drift of northeasterly derivation on top of drift brought from the mountains. It appears, therefore, that the part of the mountain drift thus covered must be of either early Wisconsin or pre-Wisconsin age. The possibility of its belonging to the Illinoian or Iowan stage is discussed on pages 69–71. The relations of the glacial deposits on the plain below the Waterton Lakes have not been studied by the writer.

BELLY RIVER GLACIER

In October, 1912, the writer, in company with Eugene Stebinger, examined some of the glacial deposits in the Belly River Valley between 6 and 10 miles north of the international boundary. (See pl. 37.) It is clear from the exposures seen that there is in this valley drift of the mountain glaciers overlain by drift of the Keewatin ice sheet. Insufficient study was made, however, to determine clearly whether this buried mountain drift is of early Wisconsin age or older. About 6 or 7 miles north of the boundary and about 2 miles south of the moraine of the Keewatin ice, there is a sharp moraine formed by the mountain ice, and from this a lateral moraine extends southward on the upland to the west. Under a well-defined terrace that heads at the moraine in the valley the following section was seen:

[97] Calhoun, F. H. H., op. cit., pp. 14–22.

Section of drift in Belly River Valley, Alberta

	Feet
6. Coarse bouldery gravel composed entirely of mountain rocks	15
5. Buff sandy silt	10
4. Grayish-buff glacial till in which a few granitic pebbles from the northeast were seen	6
3. Coarse mountain gravel	3
2. Interstratified fine gravel and sand from the mountains	6
1. Very stony mountain till	15
Bluish shale (Cretaceous).	

It is possible, though not certain, that the moraine noted marks the limit of either the early or the later Belly River Glacier of the Wisconsin stage, that with this goes the upper till (4), and that the lower till (1) and buried mountain till farther down the valley are pre-Wisconsin. Another section a little farther north showed 10 feet of stratified clay with fine pebbles, some of northeastern crystalline rocks, overlying about 50 feet of pinkish, very stony mountain till.

The northeastern crystalline pebbles in these two sections may have been dropped from ice floating on a lake held in front of the Keewatin ice. There are some indications that the Belly River Glacier was nearly 1,000 feet thick near the international boundary, as C. S. Corbett found evidence in 1914 that a lobe of the ice crossed the sag in the top of the ridge on the east to the head of Lee Creek, north of Chief Mountain. (See pls. 1 and 37.) This ice of the Wisconsin stage apparently did not reach the higher part of Makowan Butte, on which is the pre-Wisconsin drift north of the boundary, by a vertical distance of 400 or 500 feet.

About 4 miles north of the boundary is another moraine constricting the valley. Farther south is a great alluvial fan heading at the mouth of the North Fork Valley, which has forced the main stream over to the east side of the bottom land. This valley was evidently deepened 1,000 feet or more between the time of the deposition of the pre-Wisconsin drift on top of Makowan Butte and the time of the advance of the glacier of the early Wisconsin stage. The top of the butte is 1,300 feet above the Belly River.

KENNEDY CREEK GLACIER

One of the tributaries of the great St. Mary Glacier occupied the valley of Kennedy Creek just south of Chief Mountain. In 1914 C. S. Corbett and C. R. Williams, assisting Mr. Stebinger, found that the ice had spilled over the sag east of Chief Mountain and extended a lobe 3 or 4 miles down the valley of the East Fork of Lee Creek to a point less than a mile south of the international boundary, where there is a low terminal moraine. The ice in the Kennedy

Creek Valley was not, however, thick enough to override the west end of the ridge 3 miles east of Chief Mountain, which is capped with pre-Wisconsin drift (p. 33), though it extended almost to the top of this ridge. East of this the ice entirely surrounded Kennedy Ridge (pl. 37), which stood as a nunatak. The small ridge 2 miles to the northeast, which is capped with older drift, was also a nunatak at this time, the St. Mary Glacier being on the south and east sides. Between this and Kennedy Ridge and east of the latter is a strongly marked moraine, probably interlobate. Evidently there was a continuous ice field east of Yellow Mountain formed by the coalescence of the glaciers in the valleys of the North and South Forks of Kennedy Creek with that in the St. Mary Valley north of the east end of Swiftcurrent Ridge.

ST. MARY GLACIER

Conditions show that the St. Mary Valley was occupied at the Wisconsin stage by a great glacier 36 miles or more in length, which was joined by branch glaciers heading in the valleys of Swiftcurrent, Boulder, Red Eagle, and Divide Creeks. So thick was the ice in the main glacier that it crowded up onto the west slope of St. Mary Ridge to a height of 1,200 feet above the level of Lower St. Mary Lake and formed there a small but well-defined lateral moraine. This moraine curves northeastward, forming a loop and showing that the ice crowded through the broad sag in which lie Duck and Goose Lakes to the head branches of the North Fork of the Milk River. Duck Lake is 500 feet higher than Lower St. Mary Lake, and the glacial lobe thrust into this sag was about 6 miles long and 6 miles wide where it left the main glacier. After recurving about the west end of the Hudson Bay divide, a mile north of Goose Lake, the moraine swings sharply to the east again and gradually descends the north slope of the divide, thus showing that ice from the St. Mary Glacier also crowded through the gap now traversed by the St. Mary Irrigation Canal and containing Spider Lake and extended at least 6 miles down the Willow Creek Valley. Extending thence northwestward to the St. Mary River is the moraine of the Keewatin ice sheet. In the St. Mary Valley northwest of Goose Lake, above the United States Bureau of Reclamation bridge and siphon at Fletcher, the ice was fully 1,000 feet thick.

The relations of the drift of the St. Mary Glacier to that of the Keewatin ice sheet (see p. 104) seem to show that the front of the St. Mary Glacier was melted back somewhat before the Keewatin ice reached the limit of its advance, inasmuch as Keewatin drift overlaps drift of the mountain ice for about a mile south of the international boundary. The possibility of some of this low-level mountain drift being of pre-Wisconsin age is discussed on page 69. A small lobe of the glacier may have extended eastward to the head of Fox Creek through the high-level sag north of Divide Mountain where now runs the automobile road. Several more or less definite benches mark the slope below the highest lateral moraine east of Lower St. Mary Lake. These rise and converge southward and probably mark successive positions of the ice margin as the glacier was being reduced by melting. Between these and the lake is a belt of ground moraine about a mile in width, marked by marshes and ponds and by smoothly rounded elliptical swells and ridges somewhat resembling small drumlins.

After the melting of the St. Mary Glacier great bouldery fans were formed in the valley opposite the mouths of the valleys of Kennedy, Swiftcurrent, Wild, and Divide Creeks. The latter two form the dam at the north or lower end of St. Mary Lake, and that formed by Swiftcurrent Creek holds in Lower St. Mary Lake. Three soundings made in 1914 by Stebinger's party in the south half of the lower lake show depths of 50 to 70 feet of water. Three test borings made by the United States Bureau of Reclamation in a line across the valley bottom, not far below the lower end of the lake, penetrated to depths of 105 to 188 feet in gravel, boulders, sand, and clay, without reaching bedrock. The lower lake, therefore, does not lie in a rock-rimmed basin, though the stream below the outlet is cutting in sandstone, having been crowded over by the alluvial fan onto the rock at the east side of the valley.

It is probable also that there is no rock ledge at the foot of St. Mary Lake. It is not known, however, to what depths the alluvial gravel extends nor how much drift or other loose material may lie beneath it on top of the rock.

Sixteen soundings made in 1914 by Stebinger's party on transverse lines in St. Mary Lake below The Narrows show depths of water ranging from 82 to 230 feet. The depths exceeding 200 feet were all found less than 3 miles below The Narrows. (See fig. 19.) This part of the basin is excavated in Cretaceous shale. In The Narrows depths of 71 to 145 feet were found, and above The Narrows nine soundings showed depths ranging from 130 to 296 feet. The greater depths were found within a mile above The Narrows. These are due to glacial scour in the Appekunny argillite back of the massive upturned ledge of Altyn limestone. To the resistant character of the limestone is due the constriction of the basin forming The Narrows. Before the ledge was notched there was probably a waterfall here similar to McDermott Falls, in the Swiftcurrent Valley.

CUT BANK GLACIER

At the early Wisconsin stage a great glacier 20 miles long extended down the valley of the North Fork of Cut Bank Creek to a position 6 to 8 miles northwest of Browning, where a small but distinct moraine curves across that flat gravelly plain. This plain looks like an outwash plain. The terminal moraine is double and merges into lateral moraines on the north and south, showing the bulbous end of the glacier to have been nearly 5 miles wide between the high benches (No. 2), which are capped with the pre-Wisconsin drift and gravel.

About a mile inside the outer limit is a second concentric moraine, and 3 miles farther up the valley is a third. Each of these moraines merges with lateral deposits on the north and south sides. Where the automobile road crosses the valley the ice was 700 to 800 feet thick at the maximum, so that it extended nearly to the tops of the high benches. At this stage it spilled through the notch in the crest of the north ridge, 500 feet above the stream, where the road now crosses, and extended a small lobe 3 miles northeastward down the valley of the South Fork of the Milk River. The outline of this lobe is shown by a small encircling moraine. From 2 to 3 miles farther west a similar but smaller lobe spilled over a notch whose bottom is 800 feet above Cut Bank Creek.

LAKE CREEK GLACIER

A small glacier about 10 miles long occupied the valley of Lake Creek, extending eastward beyond the present automobile road, to a point within half a mile of the moraine of the Two Medicine Glacier. Northeast of the road the knolled and pitted morainal deposits merge with those of the south moraine of the Cut Bank Glacier. Where crossed by the road the moraines are poorly marked, but a little farther west a well-marked ridge about 100 feet high crosses the valley and merges with strong lateral moraines on the north and south. It is possible that the loop thus formed marks the limits of a later Wisconsin advance of the glacier rather than being simply a recessional moraine. It is bordered on the east by a gravelly flat like an outwash terrace. Two miles farther west an inner moraine loop is cut through by Lake Creek. Traced westward the south moraine extends up the slope onto a sandstone ridge rising 675 feet in 2 miles.

TWO MEDICINE GLACIER

TERMINAL MORAINE

The largest of the piedmont glaciers occupied the greater part of the Two Medicine Creek Basin. It had a maximum width of 27 miles, extended nearly 40 miles east of the mountain front, and covered approximately 800 square miles on the plains. Contributing to it were glaciers heading in the great valley in which are the Two Medicine Lakes and heading in Theodore Roosevelt Pass and in all the valleys southward to Heart Butte—a mountain frontage of 26 miles. The north boundary of the tract covered by this great glacial lobe is marked by a well-developed moraine ranging in width from a quarter of a mile or less to 3 miles. (See Browning, Blackfoot, and Cut Bank topographic maps.) The southeastern limit of the drift is not generally marked by a moraine, but it is clearly traceable by the presence of either till or boulders derived from the mountains. Besides the other mountain rocks, one characteristic constituent is conglomerate thickly set with black chert pebbles. These boulders were derived from ledges of Kootenai (?) conglomerate exposed at several places between Glacier Park station and Summit station. The presence of boulders of this conglomerate in the drift west, north, and east of Browning

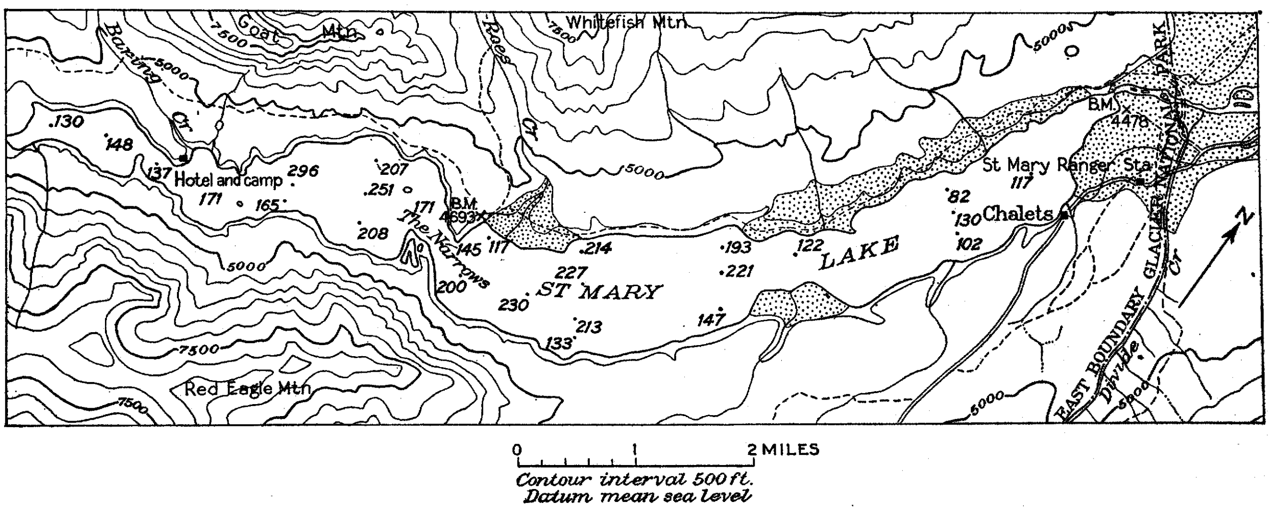


FIGURE 19.—Depths of water in St. Mary Lake, Glacier National Park, from soundings by Eugene Stebinger's party in 1914. Stippled areas, alluvial gravel fans

shows that ice from Marias Pass followed approximately the course of the railroad and crowded about the east end of the high bench 6 miles northeast of Glacier Park station, entered the valley of the South Fork of Cut Bank Creek, and came almost into contact with the ends of the Cut Bank and Lake Creek Glaciers. The same conglomerate is found clear to the east limit and is particularly noticeable along the Park to Park Highway northwestward from the point where it crosses the ridge 6 miles north of Birch Creek to the moraine west of Browning. Drift deposited by this glacier is exposed in the cuts along the old automobile road from Two Medicine Creek north of Glacier Park station up the slope to the top of the big bench east of Lower Two Medicine Lake. On this bench is a typical morainal topography marked by bouldery knolls and ponds, showing that the Two Medicine ice crowded nearly across the top of the ridge at a level about 1,000 feet above the lake. This ice did not, however, overtop the higher part of the ridge north of the lake, where the pre-Wisconsin drift occurs, by several hundred feet. East of the old road the outer moraine is well developed between the railroad and the Park to Park Highway (pl. 42 *A*), but not at the highway. The knolled and bouldery belt crossed at the jog about 4 miles west of Browning is an inner moraine. (See pl. 42 *B*.) From a point about a mile northeast of that where the Browning automobile road leaves the old St. Mary road the outer moraine extends northeastward along the south side of the Cut Bank Creek Valley. It is 2 miles wide where crossed by the main road north of Browning and nearly 3 miles wide north of Blackfoot.

Stebinger observed the following section near the bridge north of Browning:

Section of drift in moraine north of Browning, Mont.

	Feet
Soil	1
Gray loamy clay (wind-blown?)	3
Gray stony clay, till of Two Medicine Glacier	5
Nonglacial (?) gravel	4
Cretaceous sandstone.	

Parts of the moraine north of Blackfoot are very rough, in striking contrast with the smooth plain outside. (See pl. 42 *C*.) The railway and the Roosevelt Highway cross the moraine where Willow Creek [98] has cut a small postglacial gorge. Beyond this the railway runs eastward along the abandoned valley (Carlow Coulee) cut into Carlow Flat. East of Carlow station it runs up onto that flat, and thence east to the gorge west of Cut Bank both the railway and the highway traverse this terrace. This flat bench rises westward at the rate of 20 to 40 feet to the mile to the front of the moraine like an outwash plain. As shown above (pp. 47–48), however, this gravelly bench is older than the moraine and was considerably eroded before the Two Medicine Glacier encroached upon it. About 3 miles southwest of Carlow the margin of the moraine lobes down into a coulee cut in the flat, and 4 miles southeast of Carlow Stebinger found the moraine distinctly traceable down the 200-foot north side of Flat Coulee and thence more than a mile across the broad bottom and up onto the hills on the south side. Clearly Flat Coulee, which is now traversed by the Two Medicine Canal, is of pre-Wisconsin age, hence Carlow Flat is not an outwash plain. In fact, at no place did Stebinger find clear evidence of outwash deposits bordering the moraine of the Two Medicine Glacier.

The presence of drift along Two Medicine Creek down to a level 100 feet or less above the stream shows that the valley had been eroded nearly to its present depth before the Wisconsin stage of glaciation—that is, to levels 700 or 800 feet below the top of the gravel-capped remnants of No. 1 bench on the south. The eastern extremity of the lobe was in T. 31 N., R. 7 W. At its nearest point in sec. 1 the ice front was less than a mile distant from the west limit of the Keewatin ice sheet. The relations of the two drift sheets are described on pages 105–106. Stebinger found that the ice was just thick enough on the south side to crowd onto the edge of the tops of the high bench remnants west and east of the Park to Park Highway and leave there a small but definite drift ridge, in places 30 to 50 feet high, but the ice did not cross these tops. A small lobe crowded into the gap in sec. 36, T. 31 N., R. 7 W., but the ice did not reach the top of the high bench remnant east of this sag.

In the vicinity of Four Horns Lake a lobe 4 miles wide extended a few miles through a sag between high bench remnants and nearly to Blacktail Creek. Some features of the drift of this small lobe seemed to Stebinger distinctly older than the drift along a line directly southwest of Four Horns Lake. Four miles farther southwest the ice coalesced with that of a glacier in the Birch Creek Valley.

Glacial drift is spread all over the 800 square miles covered by the Two Medicine Glacier, but it is not known to be very thick anywhere. Rarely are thicknesses of more than 25 feet seen, and exposures of the underlying shale and sandstone are numerous.

AN INTERLOBATE (?) MORAINE

Branching at right angles from the outer moraine just east of Willow Creek, in secs. 22 and 23, T. 33 N., R. 9 W., a strongly developed, very rough moraine, half a mile to a mile in width, extends southwestward in a broad curve to a point on top of the ridge about 4 miles southeast of Blackfoot station. Possibly this

[98] There are numerous Willow Creeks in this region, and to avoid confusion in following the descriptions it is necessary to keep in mind which one is meant.

is really an interlobate moraine developed where the ice split over the divide between the valleys of Two Medicine and Willow Creeks. This divide stands 700 feet higher than Two Medicine Creek and about 500 feet higher than Willow Creek.

RECESSIONAL MORAINE

From 15 to 18 miles west of the eastern limit of the Two Medicine glacial drift is an inner moraine marking a stage when the glacier was considerably smaller than its maximum. This moraine is crossed by the Park to Park Highway about 6 miles west of Browning. (See pl. 42 *B*.) From this place the moraine curves and extends eastward, just north of Browning. About a mile east of the village it curves again and extends southeastward across the Park to Park Highway and the railway and for several miles across the hills beyond. About 4 miles southwest of the highway bridge a small but very distinct moraine, probably part of the same belt, runs up the south side of the valley and curves and extends southwestward 7 miles or more along the Badger Creek divide, as if marking the southeast side of the shrunken Two Medicine Glacier. Branching from this a small moraine extends southward, marking the end of a contemporaneous small lobe in the Badger Creek Valley. Here the drift is composed principally of limestone from the Paleozoic formations south of Marias Pass, but that of the Two Medicine Glacier is filled with reddish argillite from the mountains of Glacier Park. Here again there is the possibility that these inner moraines may mark the limits of a later Wisconsin readvance of the ice. Morainal deposits in T. 29 N., R. 10 W., indicate that at this stage a small separate glacier occupied the upper valley of Blacktail Creek north of Heart Butte and extended about 4 miles onto the plain.

BIRCH CREEK GLACIER

The distribution of the deposits of the piedmont glaciers in Pondera and Teton Counties and the northern part of Lewis and Clark County, as mapped by Stebinger and Goldman in 1914, is shown on their map of the Birch Creek-Sun River region,[99] but the phenomena are not described in Stebinger's paper. The deposits had been earlier studied and described, but not mapped in detail, by Calhoun.[1] The deposits north of the Sun River Valley have not been examined by the present writer. The descriptions given here are based principally on Stebinger's notes and maps. The distribution of glacial drift in the Birch Creek Valley shows that a glacier about 10 miles wide extended down the valley about 12 miles from the mountain front to a position 6 miles west of the Park to Park Highway north of Dupuyer.

As in Carlow Flat, west of Cut Bank, so here an extensive gravel-covered bench (north of Dupuyer) slopes eastward from the moraine like an outwash terrace. (See pls. 1 and 29.) The gravel on this flat, which is thought to be a remnant of No. 2 bench (p. 46), is clearly shown not to be glacial outwash from the moraine by the fact that the terminal moraine extends down the eroded marginal slopes into the valleys on both sides of the bench. Evidently the gravel-covered bench was eroded long before the last Birch Creek Glacier advanced on to it. It appears from Stebinger's mapping that the Birch Creek Glacier was really distinct from the great Two Medicine Glacier and not tributary to it. At the maximum stage, however, the ice of the two glaciers appears to have coalesced for a few miles east of Heart Butte. Beyond this they were separate. The outer morainal ridges are in places 30 to 50 feet high. Within the limits indicated there is a large amount of drift and numerous hollows, many of them occupied by ponds. The morainal drift laps up around the flanks of Scoffin Butte, a remnant of No. 1 bench 9 miles southwest of Dupuyer, in sec. 36, T. 28 N., R. 9 W., 300 feet above the creek on the north, but does not overtop the butte by more than 200 feet. In 7 miles the margin of the drift descends 700 feet from the upper limit on Scoffin Butte northeastward to the point where it is crossed by Birch Creek. Whether the ice entirely overwhelmed the great mountain wall on the west or whether it all issued from the canyon portals cut in the wall has not yet been fully determined.

Examination of the terraces on Birch Creek within the outer moraine led Stebinger to conclude that, of three levels, the highest and the second, 50 to 70 feet above the stream, were pre-Wisconsin; that the lowest probably was formed in connection with the Wisconsin glaciation; and that since the ice front retreated the stream has cut down 10 to 12 feet and developed a flood plain about 1,500 feet wide.

GLACIERS ON DUPUYER AND MUDDY CREEKS

The next piedmont glaciers to the south were small ones on the North and South Forks of Dupuyer Creek. These extended out across the foothills to points about 4 miles beyond the outer mountain wall of limestone. As shown by the moraines, they converged to the low tract between the gravel-capped mesas or bench remnants in T. 27 N., Rs. 8 and 9 W. Two smaller glaciers barely crossed the foot slope to the great alluvial fan of Blackleaf and Muddy Creeks, in T. 26 N., R. 8 W. These four glaciers headed but a few miles back of the front wall of the mountains. Calhoun described the

[99] Stebinger, Eugene, Oil and gas geology of the Birch Creek-Sun River area, northeastern Montana: U. S. Geol. Survey Bull. 691, pl. 24, 1918.

[1] Calhoun, F. H. H., op. cit., pp. 14–22.

moraine on Blackleaf Creek as a sharp ridge 200 feet in height.

TETON RIVER GLACIER

Two streams but half a mile apart issue from deep, narrow gaps in the mountains and, joining a mile or two below the mouth of the canyon, form the Teton River. The ice apparently entirely filled the north and south gorges cut through the Teton anticline (pl. 29), east of the mountain wall, being 700 to 800 feet thick in the north gorge and about 600 feet thick in the south gorge, and it extended 4 miles farther east on the low flat plain. Of this glacier Calhoun [2] wrote:

> The glacier thus formed, though extending but a few miles east of the mountains, gives evidence of having been very powerful and active. The terminal moraine on the north side of the river consists of a series of sharp ridges, which form a belt over a mile wide. They are so steep and are covered with so many limestone boulders that the moraine is difficult to cross on horseback. The terminal moraine is covered with a growth of stunted pine trees, which are found neither on the ground moraine nor on the plain to the east. The north and south edges of the ice formed two moraines which extend parallel to each other for a distance of 6 miles from the mouth of the canyon. They are about 3 miles apart and are well developed throughout their entire extent. This development of the moraines along the side of the glacier is in sharp contrast to that formed at the end of the ice.

A small glacier south of Ear Butte, at the head of the South Fork of Willow Creek, scarcely reached the plain.

DEEP CREEK GLACIERS

Stebinger found moraines extending about 2 miles from the mountain front on both sides of the North and South Forks of Deep Creek, in T. 23 N., R. 8 W., showing that two small glaciers reached the plain west of Long Ridge, an outlying gravel-capped mesa (remnant of No. 1 bench), and 500 feet lower than its top. The mountain canyons on these streams are only about 6 miles long.

SUN RIVER GLACIER

OUTER MORAINE

The piedmont glacier on the North Fork of the Sun River in Lewis and Clark and Teton Counties was exceeded in size only by the great Two Medicine Glacier. As shown by the moraines mapped by Stebinger, the ice filled the canyon "gateway" or "portal" (pl. 43) and overrode the top of the lower mountain wall (pl. 7 *A*) as a valley glacier 4 miles wide. Passing the foothills it deployed on the gently undulating plain until it reached a maximum width of about 15 miles, north to south, and a length of 18 miles, measured southeastward to the point where the North Fork of the Sun River cuts through the terminal moraine north of Gilman. It covered more than 200 square miles on the plains. On the north the ice reached the high bench on the south side of Deep Creek and extended down that valley to a point 14 miles southwest of Choteau. At 12 miles a little north of east from the canyon "portal" the ice encountered the wedge-shaped west end of the gravel-capped mesa (No. 1 bench) and crowded up the steep slope 400 feet above the plain to the west. It did not overtop the head of the bench by 100 feet or more. From this point the terminal moraines gradually descend along the slope to the northeast and to the southeast. In the latter direction the moraine is traversed for several miles and finally overtopped by the Sun River Slope Canal. In places, as shown by the position of the moraine (pl. 44 *A*) the ice just overtopped No. 2 bench. This may be seen north of the North Fork of the Sun River and also on the ridge between Gilman and the south side of the North Fork. The ice was therefore over 200 feet thick at these points on the margin. It was about 1,500 feet thick at the mouth of the canyon. For 5 or 6 miles northward from the vicinity of Augusta and Gilman the Park to Park Highway runs near or along the knolled and bouldery terminal moraine.

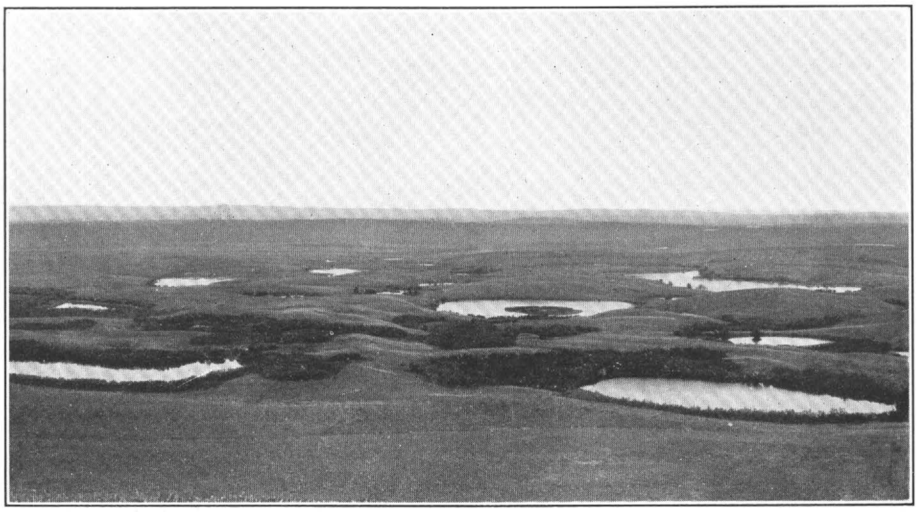
In the Sun River Valley north of Gilman and in the vicinity of Gilman and Augusta a broad gravelly flat borders the front of the moraine like an outwash terrace. This extends down the valley to the east as the No. 3 terrace. No evidence was noted here that the gravelly flat is older than the moraine. The stratified gravel beneath the terrace extends westward into or under the moraine.

The outer moraine extends in a broad curve across the plain north of Augusta. At and west of the cemetery it lies on a low ridge, then passes about the east end of the high bench remnant and lies along its north slope. About 6 miles west of Augusta the moraine runs up on to the head of the No. 2 bench remnant, crosses it, and recurves sharply eastward in sec. 17, T. 20 N., R. 7 W. Evidently for nearly 5 miles in the sag west of this high point the ice of the Sun River Glacier coalesced with that of the next glacier to the south.

INNER MORAINES

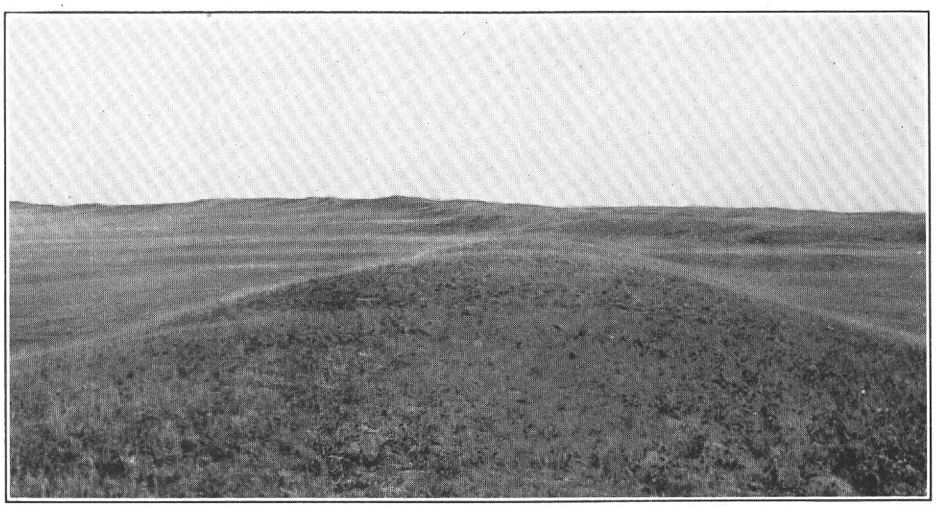
Branching from the outer moraine on the slopes of the high benches north and south of the Sun River are two well-marked and very bouldery inner moraines. These indicate one of two things—either that the ice continued tightly crowded against the slopes of the high mesas while its front in the valley between was melted back about 3 miles; or that these inner moraines are the product of a later Wisconsin readvance of the ice against the high mesa slopes, but not so far down the valley. The Willow Creek Reservoir lies

[2] Calhoun, F. H. H., op. cit., p. 17.



A. VIEW 7 MILES SOUTHWEST OF BROWNING, SHOWING NUMEROUS SMALL LAKES

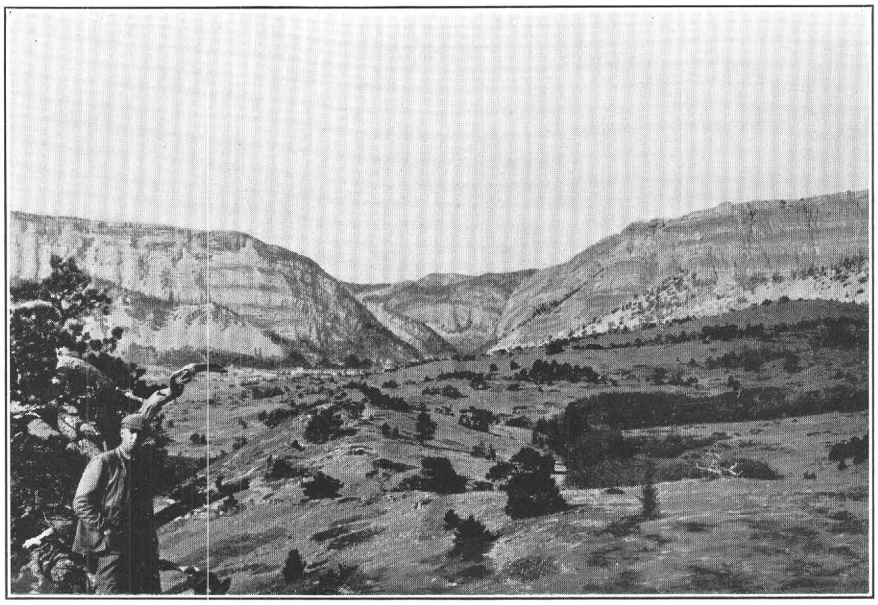
B. VIEW 4 MILES WEST OF BROWNING, NEAR PARK TO PARK HIGHWAY



C. VIEW 8 MILES NORTHEAST OF BROWNING, ALONG THE CREST

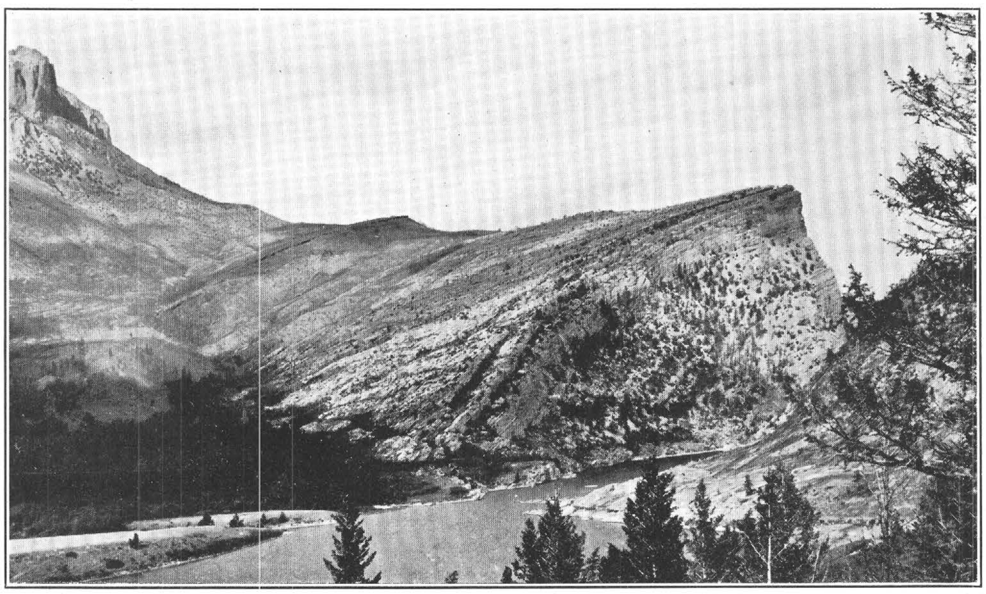
Showing the front of the moraine curving off to the left in the background. Photograph by Eugene Stebinger.

MORAINES OF TWO MEDICINE GLACIER, BLACKFEET INDIAN RESERVATION, MONT.



A. MOUTH OF THE CANYON FROM FOOTHILLS SEVERAL MILES EAST

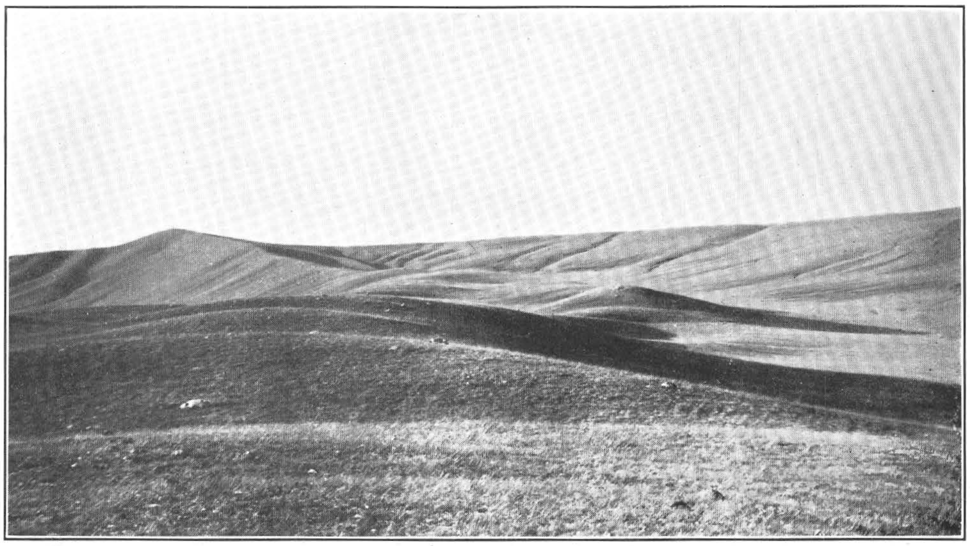
Showing the notch cut nearly 1,000 feet deep through the lower limestone wall, probably in interglacial time.



B. VIEW NORTHEAST TO THE MOUTH OF THE CANYON AND OVER THE TOP OF THE LOWER WALL OF LIMESTONE FROM THE INSIDE

At the Wisconsin stage of glaciation the ice filled the big notch and overtopped the limestone wall. The Bureau of Reclamation dam is in the gorge at the right.

SUN RIVER CANYON, MONT.

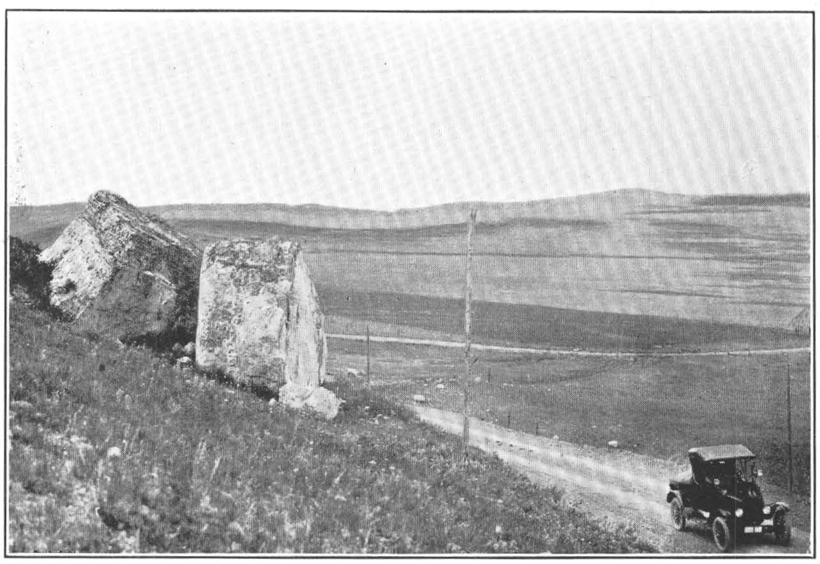


A. TERMINAL MORAINE OF SUN RIVER GLACIER 4 MILES NORTH OF GILMAN, MONT.

View north from Park to Park Highway, showing the moraine extending from the Sun River Valley up onto No. 2 bench in the background. The glacier lay at the left (west). Photograph by Eugene Stebinger.

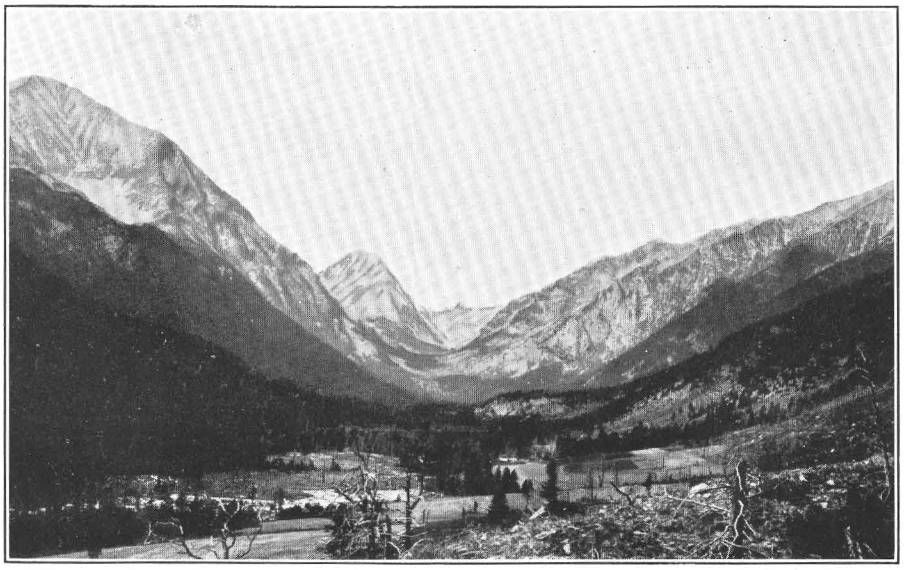
B. BLOCKS OF PALEOZOIC LIMESTONE TRANSPORTED BY SUN RIVER GLACIER, ON THE PLAIN 8 MILES EAST OF THE MOUTH OF THE SUN RIVER CANYON

The blocks are 10 by 13 by 30 feet.

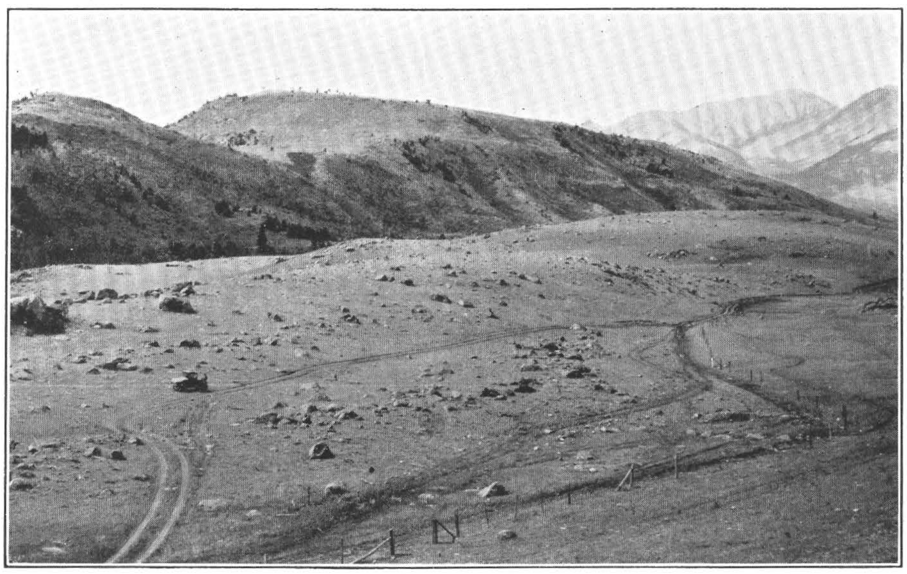


C. BLOCKS OF PALEOZOIC LIMESTONE TRANSPORTED BY SUN RIVER GLACIER 4 MILES NORTHWEST OF AUGUSTA, MONT.

On moraine 15 miles southeast of the mouth of the Sun River Canyon. The blocks are 15 to 20 feet long.



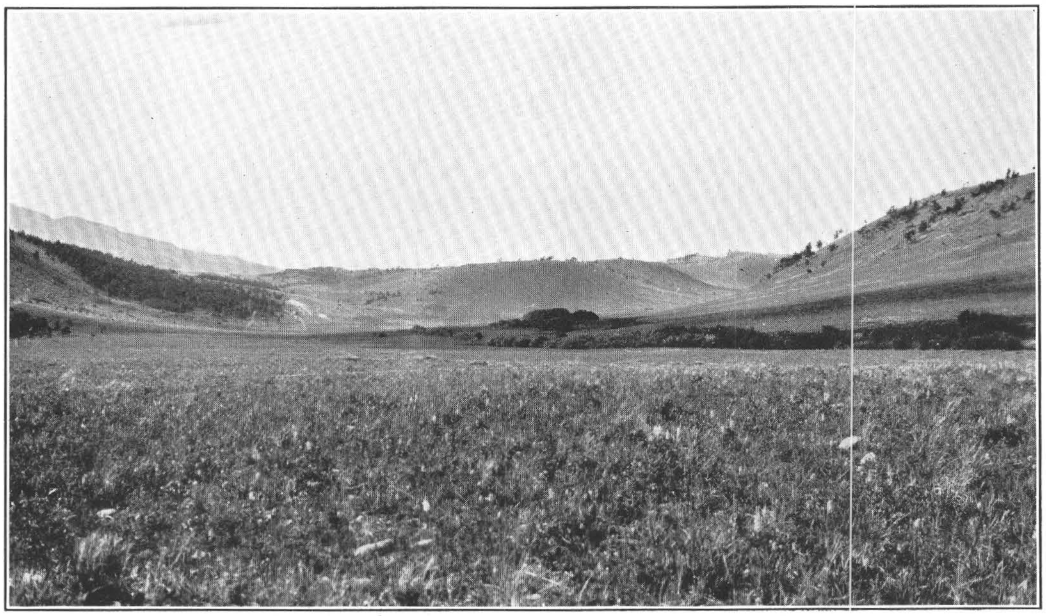
A. GLACIATED CANYON OF BIG TIMBER CREEK



B. BOULDERY TERMINAL MORAINE OF BIG TIMBER GLACIER, OF WISCONSIN STAGE

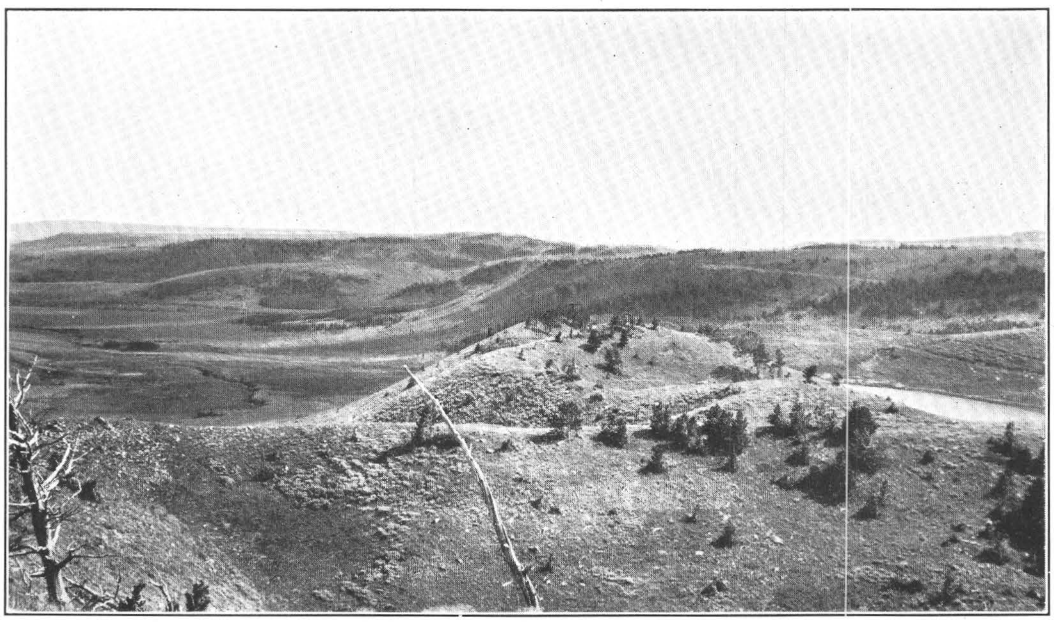
In foothills 2 miles east of the mountains.

CRAZY MOUNTAINS, MONT.



A. VIEW LOOKING UP NORTH FORK OF SWAMP CREEK

The moraine forms a dam 150 feet high completely blocking the valley in the middle background.

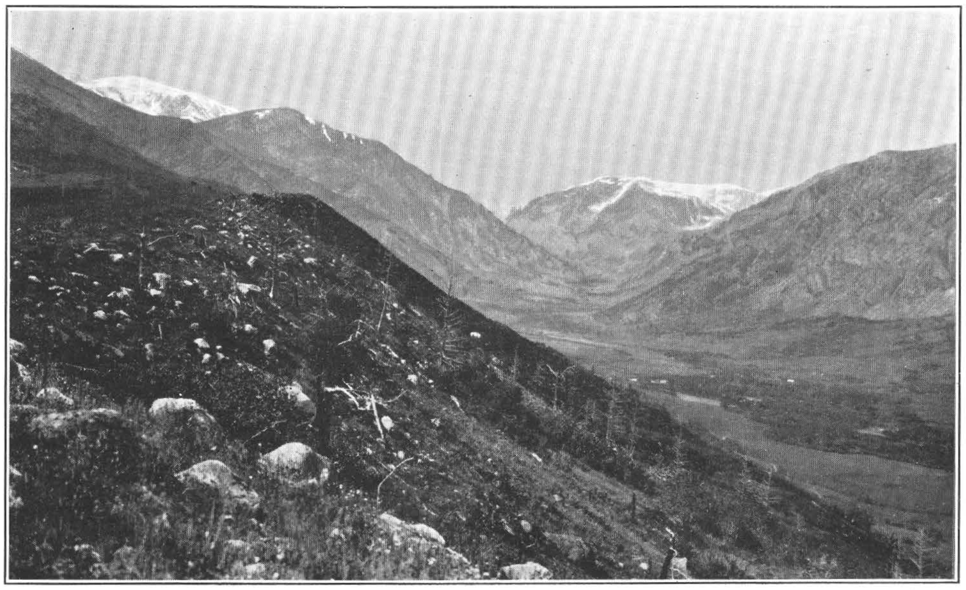


B. TOP OF THE MORAINE

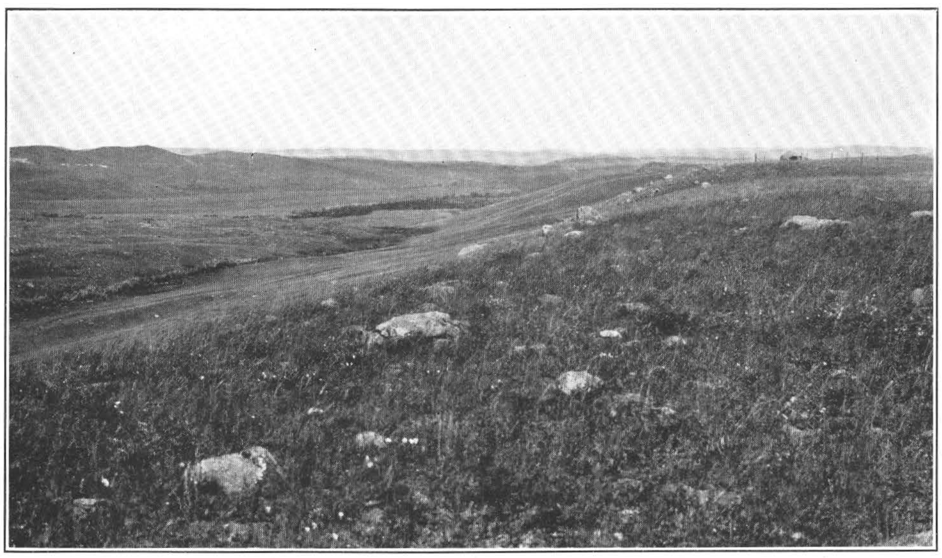
Swamp Creek Valley in middle ground at left; remnant of No. 1 bench in background.

VIEWS NEAR CRAZY MOUNTAINS, MONT.

Showing terminal moraine of glacier that occupied the valley of South Fork of Big Timber Creek.

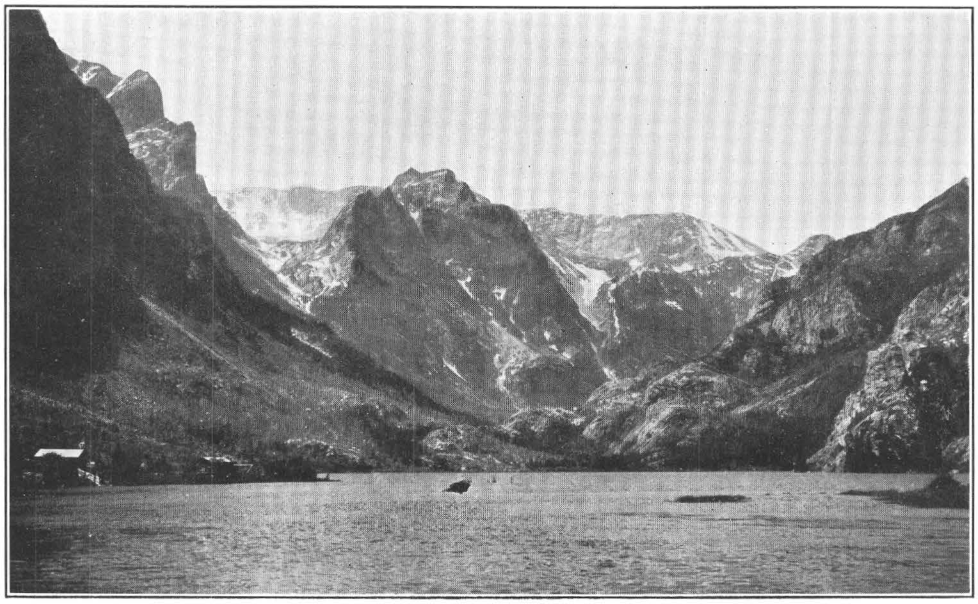


A. EAST ROSEBUD CANYON, BEARTOOTH MOUNTAINS
Lateral moraine on edge of No. 2 bench in left foreground.

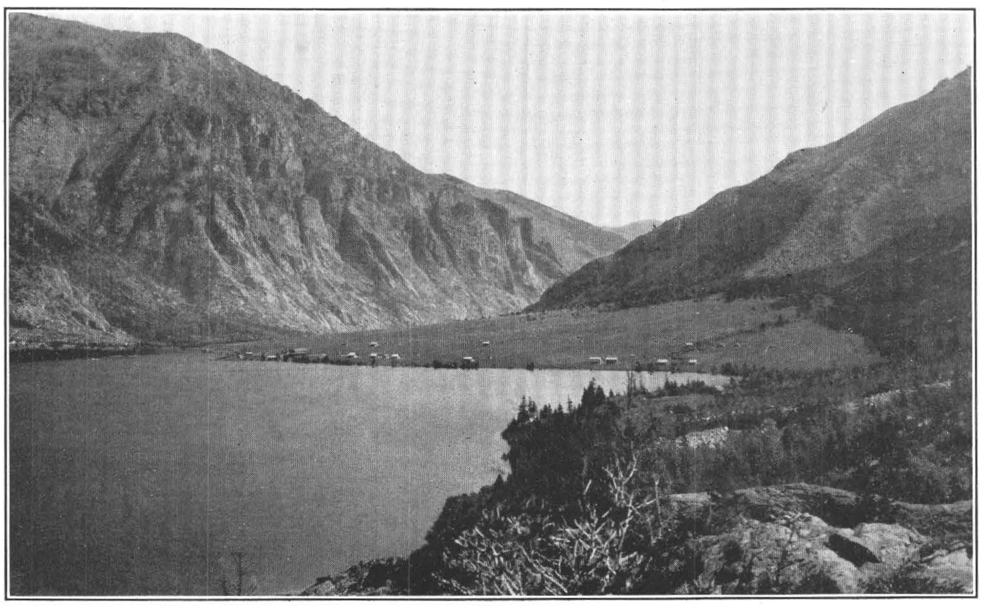


B. OLDER LATERAL MORAINE (ILLINOIAN OR IOWAN?) ON No. 2 BENCH (AT RIGHT) AND YOUNGER LATERAL MORAINE (WISCONSIN) DESCENDING TO VALLEY BOTTOM (IN LEFT MIDDLE GROUND)

MORAINES OF EAST ROSEBUD GLACIER SOUTH OF ROSCOE, MONT.

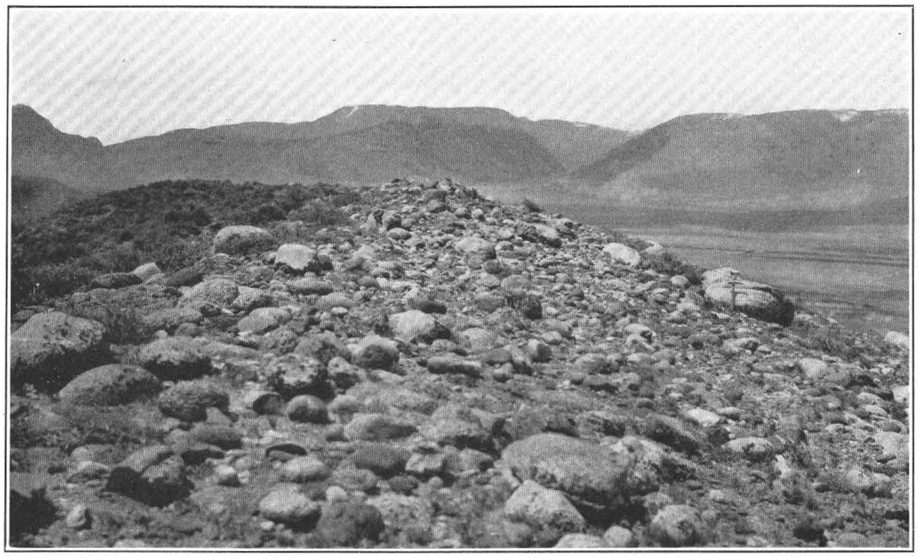


A. EAST ROSEBUD LAKE AND MOUNTAINS



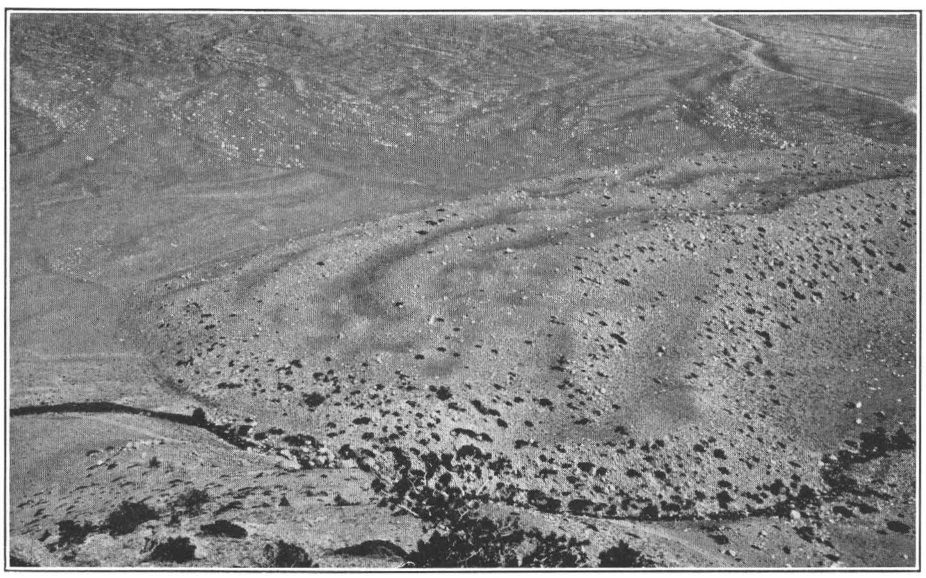
B. ALLUVIAL FAN THAT FORMS THE DAM AT THE FOOT OF EAST ROSEBUD LAKE

EAST ROSEBUD CANYON, BEARTOOTH MOUNTAINS, MONT.



A. COARSE BOULDERY GRAVEL (PLEISTOCENE) CAPPING A REMNANT OF No. 2 BENCH NORTHEAST OF CLARK, WYO., 4 MILES SOUTH OF THE MONTANA-WYOMING STATE LINE

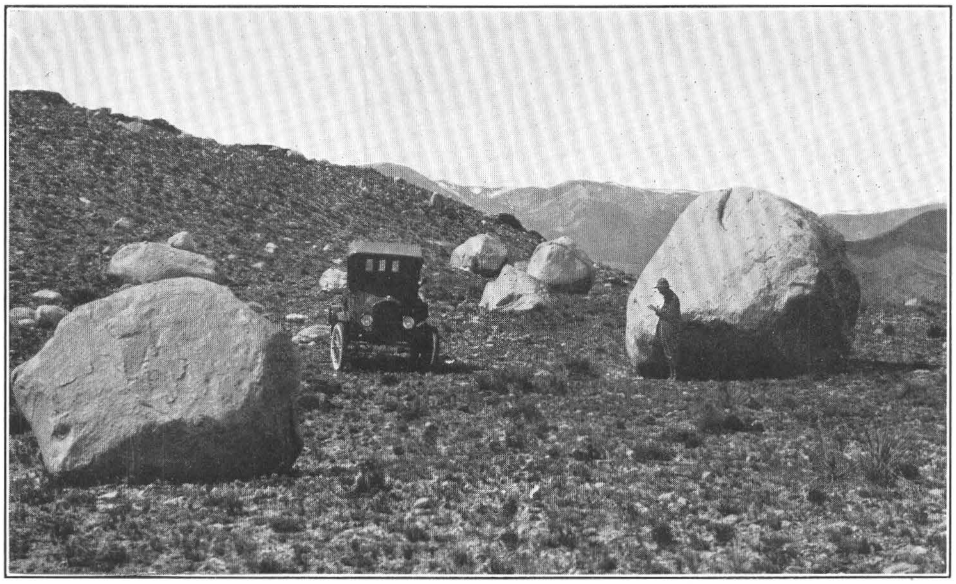
Beartooth Plateau in background.



B. TERMINAL MORAINE OF CLARK FORK GLACIER, OF WISCONSIN STAGE, AS SEEN FROM HIGH BUTTE ON THE NORTH, 4 MILES WEST OF CLARK, WYO.

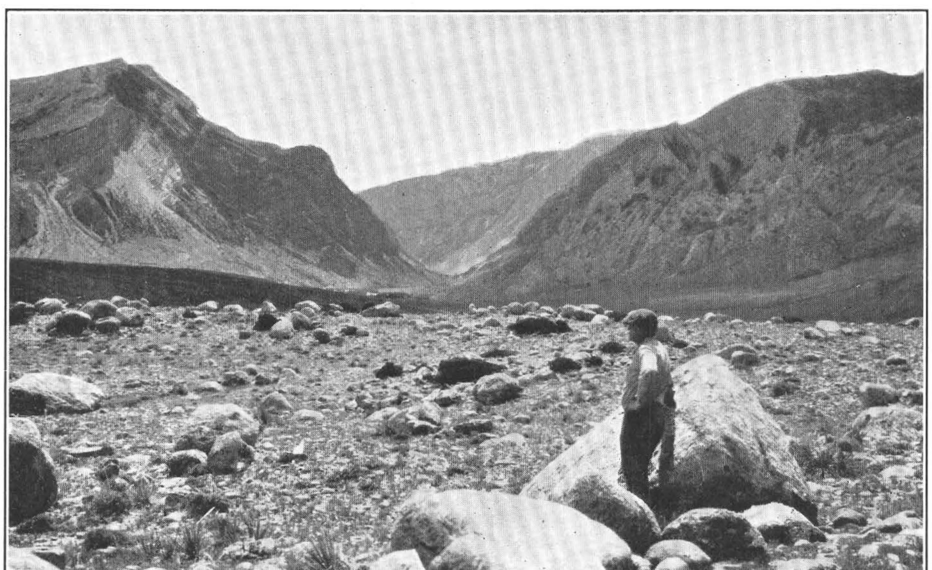
The moraine is in the right middle ground; the bordering bouldery plain at the left and in the background.

VIEWS ON CLARK FORK OF THE YELLOWSTONE RIVER



A. FRONT OF TERMINAL MORAINE OF CLARK FORK GLACIER, OF WISCONSIN STAGE, 4 MILES WEST OF CLARK, WYO.

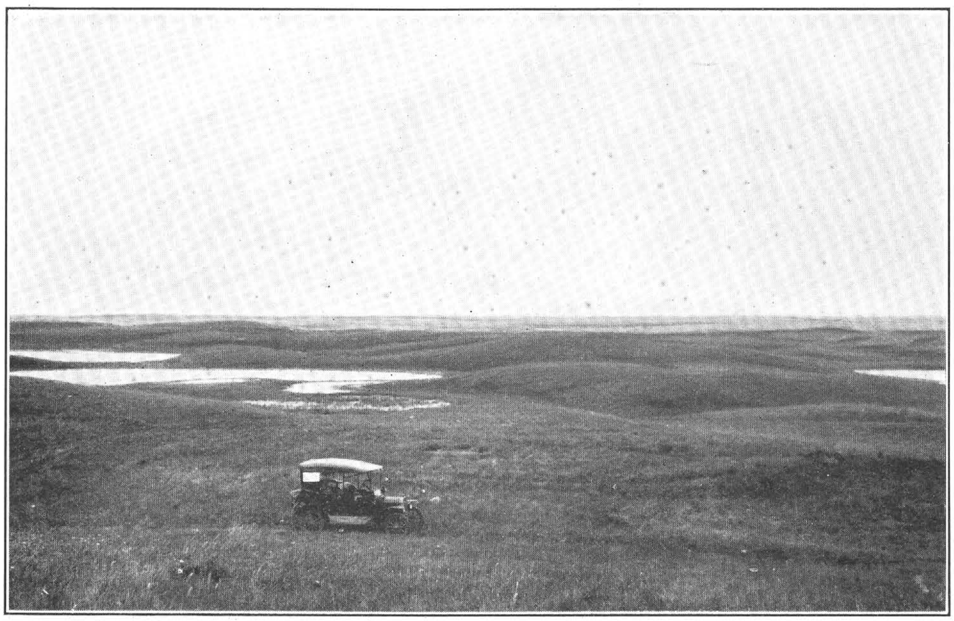
Showing granite boulders 5 to 15 feet in diameter.



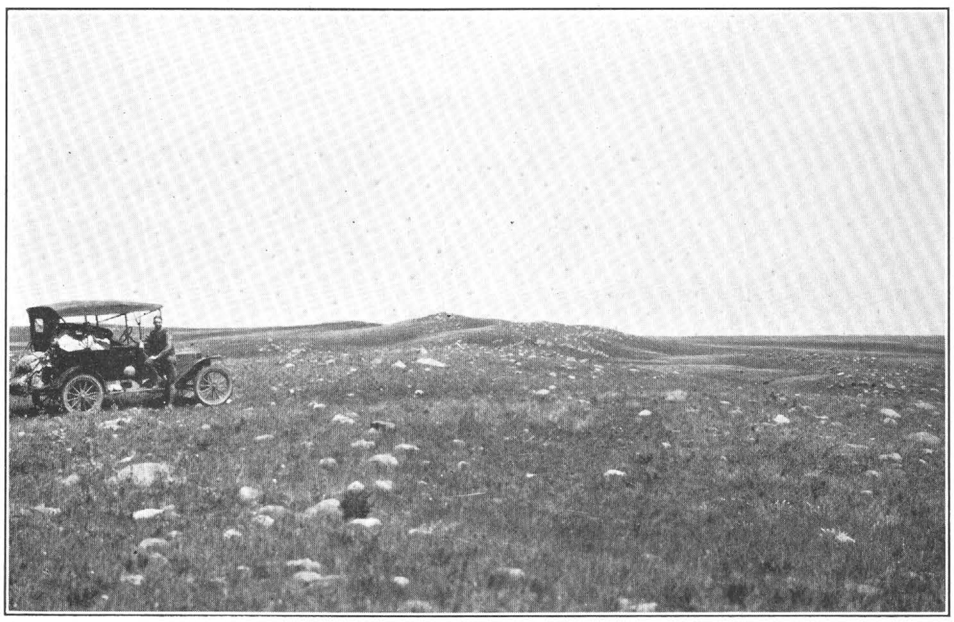
B. BOULDERY TOP OF TERMINAL MORAINE OF CLARK FORK GLACIER

Mouth of Clark Fork Canyon in middle background, 2 miles distant; Bald Mountain at left.

VIEWS ON CLARK FORK OF THE YELLOWSTONE RIVER



A. COTEAU DU MISSOURI, BURKE COUNTY, N. DAK.



B. VIEW 20 MILES NORTH OF WHITETAIL, MONT., WEST OF BIG MUDDY LAKE, WILLOWBUNCH DISTRICT, SASKATCHEWAN

TERMINAL MORAINE OF KEEWATIN ICE SHEET, LATER WISCONSIN STAGE within the inner of these two belts. Similarly an inner moraine incloses the basin of the Pishkun Reservoir and extends thence west to the mountain front about 2 miles south of the outer north moraine. Coordinate with this is a moraine extending northwestward from Willow Creek on the east side of Barr Creek, 1 to 2 miles inside the upper southwestern limit of the ice, which is traceable but not marked by a definite moraine.

Inside these limits drift composed of mountain rocks is generally present. There are many ponds when the season is not too dry. Some of the low ridges may be of shale rather than drift. Among the many boulders are some very large ones. One of limestone (pl. 44 *B*) at the cross roads north of the North Fork of the Sun River in sec. 17, T. 22 N., R. 7 W., about 7 miles east of the mountains, measures 30 feet long and 13 feet high. It is split into two parts, each about 10 feet thick. Its weight is estimated as about 100 tons. Two similar blocks 15 to 20 feet long (pl. 44 *C*) lie on the slope above the road 3 miles west of Augusta Cemetery.

SMITH CREEK GLACIER

Conditions on the plain west of Augusta and north of Haystack Butte show that ice on the headwater branches of Willow, Ford, and Smith Creeks combined in one glacier which extended about 10 miles out from the mountains. The outer moraine is continuous with that of the Sun River Glacier on the head of the gravel-capped ridge (No. 2 bench) 7 to 8 miles west of Augusta. Curving sharply to the east, it runs down the south slope of the ridge and extends 3 to 4 miles down the valley. It crosses the plain in a broad curve and may be traced thence southwest along the slope north of Haystack Butte. Northeast of the latter butte the ice crowded into Swallow Canyon, and here there are several lakelets in basins in the drift. Northwest of this butte a great dam of drift blocks what appears to have been the preglacial valley of Gap Creek when it was tributary to Smith Creek.

DEARBORN GLACIER

A piedmont glacier extended 6 miles or more northeast of the mouth of Dearborn Canyon down what appears to be the pre-Wisconsin valley of the river. This valley, northeast of Bean Lake, is now traversed by an irrigation ditch; and that part near the Park to Park Highway is drained by Flat Creek. Several moraines cross the valley within 4 or 5 miles northeast of Bean Lake. These were not mapped in detail. The ice extended nearly 2 miles north of Bean Lake, and on the southeast it extended to the ridge east of the Dearborn River bridge. Till with striated boulders was exposed in the road cut south of the river when seen by the writer in 1921.

CASTLE MOUNTAIN GLACIERS

For more than 50 miles southeastward from Dearborn Canyon on an air line to the Castle Mountains no glaciers are known to have extended from the mountain gorges out onto the plains, and no evidence of glaciation has been found in the outlying mountain groups. Weed found no evidence of glaciation in the Little Belt Mountains unless it be the presence of two cirquelike amphitheaters on the southeast side of Big Baldy Mountain, 8 miles east of Neihart, at 8,000 to 9,000 feet above sea level.

In the Castle Mountains (pl. 1), the highest point of which, Elk Peak, rises to 8,606 feet above sea level, in the southern half of Meagher County, there were glaciers at the Wisconsin stage of glaciation. The possibility that some of the bouldery drift on the ridges bordering Alabaugh Creek on the south side of the mountains west of Lennep was deposited at an earlier stage of glaciation is discussed on page 40.

A later terminal moraine described by Weed as blocking the valley north of Castle probably marks the limit of the glacier at the Wisconsin stage. It has not been examined by the present writer. A brief examination of the Fourmile Creek Valley, on the north side of the mountains, 8 miles east of White Sulphur Springs, was made in August, 1921, and bouldery morainal deposits were found at and above the ranger station, about 3 miles up the gorge from the main road. Weed describes a moraine farther up the valley as belonging to the "retreating phase" of the glacier. It is quite possible that some of the drift on the interstream ridges on the flanks of the mountains, like that on Alabaugh Creek, is really pre-Wisconsin.

CRAZY MOUNTAIN GLACIERS

Evidences of glaciation in the Crazy Mountains were described by Wolff,[3] by Iddings and Weed,[4] and later by Mansfield.[5] The relations of the terminal moraines of several of the glaciers were examined by the present writer in the course of brief reconnaissances about the margins of the mountains, in 1921 and 1922. These mountains are extremely rugged, with very steep slopes and numerous pyramidal peaks rising high above timber line and culminating in Crazy Peak, 11,178 feet above sea level. There is a whole row of glacial cirques high on the north slope of the north group of the mountains, but glaciers from these appear not to have reached low levels. Several of the other glaciers extended far enough out of the mountain gorges to show their relations to remnants of the

[3] Wolff, J. E., The geology of the Crazy Mountains, Mont.: Geol. Soc. America Bull., vol. 3, p. 446, 1892.

[4] Iddings, J. P., and Weed, W. H., U. S. Geol. Survey Geol. Atlas, Livingston folio (No. 1), pp. 1–2, 3, 1894. Weed, W. H., idem, Little Belt Mountains folio (No. 56), pp. 6, 7, 1899.

[5] Mansfield, G. R., Glaciation in the Crazy Mountains of Montana: Geol. Soc. America Bull., vol. 19, pp. 558–567, 1907.

benches described above (pp. 24, 51). Drift mapped by Weed on upper Big Elk Creek, which was deposited by ice heading in the eastward-facing chambered amphitheater formed by the flanks of Cinnamon, Loco, and Lebo Peaks, was not examined by the writer.

The Sweetgrass Canyon was occupied by a glacier which had a length of 16 to 18 miles. The thickness of this glacier was so great (700 to 1,000 feet) where it issued from the mountain gorge that it overtopped the high ridge on the east and laid a lateral moraine along its crest. A few miles farther north it entirely overrode the lower end of this ridge and spread eastward onto the plain below. Not far north of the pond on the rock ridge the main ridge of the moraine loops across a ravine and there is a smaller drift ridge outside; east of this there is no drift on the rock spur. To the north the ravine bifurcating the rock ridge becomes a U-shaped trough, down which the ice moved and from which it spread out to the east. The lateral moraine curves sharply to the east and extends down the bluff to the plain below.

On this plain is a broad tract which is marked by bouldery knolls and basins extending eastward to the road on the gravel terrace at about 5,600 feet above sea level. The main stream of ice extended down the valley, about the north end of the rock ridge, and also spread over the upland to the north. Weed's map shows drift extending northward to American Fork. Cuts for an irrigation ditch and for the road on the face of the south side of the gorge near the bridge expose 75 feet of coarse bouldery material. The upper 10 feet, at least, of this is glacial till. The material below is more waterworn and contains less fine material but is not well bedded. To the north of Porcupine Butte can be seen the abrupt west end of a remnant of No. 1 bench. Similar high remnants are in view off to the south. Since the melting of the glacier Sweetgrass Creek has cut a gorge about 100 feet deep west of Porcupine Butte, but this depth of cutting does not extend far up the valley. Part of the valley bottom is flat and marshy.

About 4 miles above the boundary of the Absaroka National Forest the wooded canyon is narrowed by projecting rock spurs, and the stream plunges over a great ledge of porphyry down into a small box canyon, forming a series of beautiful cascades in a tortuous channel marked by great potholes. The rock ledges along the trail above the sides of the box canyon are smoothed, scratched, and grooved as the result of the glacial action. At one point the trail follows a large glacial groove for several yards. The box canyon is postglacial. Glacially scratched ledges were seen more than 1,000 feet above the forks of the creek on the north side of the canyon. The heads of the gorges are scalloped by many high-level cirques.

The valley of Big Timber Creek (pl. 45 *A*) is obstructed about 2 miles east of the national forest boundary in the foothills by a great deposit of morainal drift, thickly strewn with large boulders (pl. 45 *B*), many of which are 10 or 15 feet in diameter. About a mile farther west similar blocks of porphyry 15 to 30 feet long appear to have slid down from the hill at the north. About a mile inside the national forest boundary the ice completely filled the trough and laid its south lateral moraine on top of the narrow-crested ridge on the south. This crest rises westward to the flank of Crazy Peak. In the adjacent part of the gorge the ice was 700 to 1,000 feet or more thick. All the foothills up to nearly 7,000 feet above sea level were probably overtopped by No. 1 bench, so that there was probably nearly 1,000 feet of valley deepening at the mountain front below No. 1 bench before the Wisconsin glaciers advanced.

The valley of the middle fork of Big Timber Creek was not examined by the writer. The canyon of the south fork is anomalous, in that it appears to have been tributary to Swamp Creek prior to the Wisconsin stage of glaciation. The Swamp Creek Valley is bordered by finely preserved remnants of both No. 1 and No. 2 benches. The north branch of the north fork of Swamp Creek is cut across the heads of these benches and 200 to 500 feet below their smooth tops and separates them from the foot slope of the mountains. On going up this branch valley the writer found it completely blocked, just inside the national forest boundary, by a great morainal dam (pl. 46) 100 feet in height. The relations show clearly that a glacier in the canyon of the south fork of Big Timber Creek crowded into this branch of the Swamp Creek Valley and deposited the morainal drift dam. Inasmuch as the valley of the south fork of Big Timber Creek was seen by the writer only from a distance, it can not be asserted positively that the canyon formerly drained to Swamp Creek, though this is suggested by what was seen of the relations, which are not accurately shown on the Livingston topographic map. The stream now flows eastward through a sharp postglacial cut 600 to 800 feet below the level of the top of No. 1 bench (Raspberry Butte).

The canyon on the south fork of Swamp Creek was occupied by a glacier about 5 miles in length, which headed north of Fairview Peak and extended a short distance beyond the national-forest boundary and made a moraine there. The ice was so thick that it overtopped the big ridge on the south and laid a bouldery lateral moraine along its crest.

A glacier heading in high-level cirques on the westerly flanks of Iddings Peak extended southward and curved to the southwest in the trough between the high remnants of No. 1 bench, ending near one of the southwest corners of the national forest, about 6,000 feet above sea level.

Mansfield refers to a glacier having occupied the Pine Creek Canyon, in the western part of the mountains. Apparently it did not extend far outside the national-forest boundary, as no moraine was seen by the present writer in a trip along the valley below the big bench (No. 2) on the north.

Glacial ice heading west of Sunlight Peak extended northward a few miles down tributaries of the Shields River. The most westerly part of this ice was so thick as to overtop the long ridge on the west and lay its bouldery lateral moraine along the crest of the ridge, but not to overflow to the west. This ridge is probably a remnant of No. 1 bench.

It is clear that the outer moraines of all these glaciers in the Crazy Mountains were formed after the valleys had been cut nearly to their present depths, hundreds of feet below No. 1 and No. 2 benches. The third bench was not found developed in such places as to show clearly its relations to the glacial moraines.

YELLOWSTONE GLACIER

Evidences of glaciation in the Yellowstone Valley and in the Boulder River canyons north of the national park were described by Weed.[6] Brief examinations were also made by the present writer in 1921, 1922, and 1923. A great glacier heading in and adjacent to Yellowstone National Park extended down the river valley to the vicinity of Chicory station and the mouth of Mill Creek. The bouldery terminal moraine is crossed by the automobile road on the west side of the valley at a point about 18 miles from Livingston and 5,100 feet above sea level. The moraine is in distinct contrast with the smooth gravel plain in front, but it is not a high or bulky ridge. It appears to be laid down on a great alluvial gravel fan heading to the west on Eightmile Creek. This may be No. 3 bench, and not an outwash terrace. The hummocky moraine is strewn with boulders as much as 15 feet in diameter. After the recession of the ice front the creek cut back through the moraine northeast of Chicory station. The moraine can scarcely be seen from the railway, down in the inner valley which the river has cut about 200 feet deep through the moraine and underlying terrace. About a mile south of Chicory station an inner moraine appears to extend down over the eroded edge of the bench and to have originally extended across the bottom of the inner valley to and up the eroded edge of the bench on the east side.

The automobile road on the east side of the valley runs partly on and partly below No. 3 bench. About 23 miles from Livingston on this side the terminal moraine is found on No. 3 bench between Elbow and Mill Creeks. The boulder-strewn humps and hollows extend in a belt half a mile wide southward from the eroded edge of the terrace to the foot of the mountain slope. Apparently a glacier heading in the Mill Creek Valley here joined the Yellowstone Glacier. From 2 to 3 miles west of Mill Creek the very bouldery inner terminal moraine extends southward across the flat terrace to the mountain front. Near the Hot Springs Hotel and the old village of Chico the road skirts the east side of the moraine. Just west of Chico Emigrant Creek cuts through the big moraine. Thence southwestward the moraine extends for several miles up the valley at the foot of the mountain slope to the vicinity of Duck Lake. Beyond this point it was not examined by the writer.

Glaciers extended down several of the gorges which cut the west flank of the Absaroka Range from Livingston Peak and Mount Delano to Mount Cowen, north of Mill Creek. Not all these gorges have been examined by the present writer. On the north fork of Deep Creek the terminal moraine is at 5,500 to 5,700 feet above sea level, at the head of a smooth bouldery terrace about a quarter of a mile below the national forest boundary.

The relations of the several moraines and terraces require further study for their clear interpretation, but, so far as seen, there seems to be evidence of two advances, either an earlier and a later phase of the Wisconsin glaciation, or the earlier one is of Iowan or Illinoian age and a correlative of Blackwelder's "Bull Lake stage" of glaciation in the Wind River Basin, Wyo.

Between Pool and Pine Creeks is a steep narrow-crested spur about 700 feet high extending out from the foot of the mountain. This appears to be a great lateral moraine, or else it is a ridge capped by bouldery drift. The ridge lowers rapidly to the west and is separated from a similar ridge on the opposite (south) side by a narrow gorge cut 200 to 300 feet deep in gray bouldery till. Outside this and somewhat to the south an outer moraine extends nearly to the road, and from this moraine a very bouldery dry channel extends to the river.

The inner moraine of the Yellowstone Glacier appears to extend down over the eroded edges of the big terrace and across the inner valley bottom just south of Chicory. Nothing was noted below the mouth of Mill Creek, near Pray station, however, which could be regarded as indicating clearly that the outer moraine is younger than the main big terrace. If it ever extended down into the inner valley it was later cut away in forming the lower terrace levels, so that no trace remains. The big terrace is, however, equally well developed and preserved inside both the outer and the inner moraines, giving rise to the suggestion

[6] Weed, W. H., The glaciation of the Yellowstone Valley north of the park: U. S. Geol. Survey Bull. 104, 1893; U. S. Geol. Survey Geol. Atlas, Livingston folio (No. 1), 1894.

that it is older even than the outer moraine, just as Carlow Flat, in the Blackfeet Indian Reservation, is older than the outer moraine of the Two Medicine Glacier, whose front it borders. The relation of the gravel to the basalt farther up the valley is discussed on page 62. If the gravel of the terrace is really the same as that overlain by the basalt at and above Emigrant, it is evident that the terrace is older than the outer moraine, which was laid down upon it, like the inner moraine.

BOULDER RIVER GLACIERS

The relations of morainal and other deposits on the bottoms of the three branches of the Boulder River Valley show that these valleys and that of the trunk stream had about the same depths and other dimensions prior to the Wisconsin stage of glaciation as now. No. 3 terrace is well preserved for 5 or 6 miles above the Big Timber bridge, and below the third terrace is a fourth 10 to 20 feet above the flood plain. It seems probable, though it was not certainly determined, that this fourth terrace was formed at the Wisconsin stage of glaciation. It is about 250 feet below the level of No. 2 bench and 500 to 600 feet below that of No. 1 bench. Farther up the valley the third and fourth terraces appear to merge; at least they have not been differentiated. This lower terrace and the bed of the stream are notably bouldery, there being many well-rounded boulders 1 to 3 feet in diameter near the Big Timber bridge, and about 12 miles up the valley, near the bridge below McLeod,[7] 3 to 4 foot boulders of a great variety of igneous rocks are numerous along the road. Just above the McLeod bridge a great bouldery moraine half to three-quarters of a mile wide lies in the mouth of the West Boulder Valley. The road crosses this moraine at 4,800 to 4,900 feet above sea level to the less-filled valley above. This moraine marks the limit of the West Boulder Glacier. About 4 or 5 miles farther up the valley is another more extensive and very bouldery moraine on the broad valley bottom and extending west of the river for about 1½ miles up into the recess in the slope that is traversed by the Livingston road. There are many big crystalline boulders here, some 20 to 30 feet in maximum diameter. For several miles south of the bridge the ice was so thick (500 to 600 feet) that it overtopped the bluffs and, on the east side, laid a great lateral moraine along a bench a mile in width which borders the higher driftless part of the ridge north of the Absaroka National Forest boundary.

The main Boulder Glacier appears to have not quite reached a junction with that on the West Boulder River. The moraine, as seen from the road, is less than a mile above the confluence of the streams. It is possible that at some stage the ice entirely overtopped the sag in the crest of the big ridge a few miles farther southwest. In this main valley there is an inner moraine just north of the belt of red shale near the national-forest boundary. The valleys of the East Boulder River and Elk Creek combine into a broad basin, in which there is an extensive deposit of glacial drift, 50 to 60 feet being exposed in the stream banks in places. This drift appears to have been deposited by a glacier heading in the East Boulder Canyon, though the canyon portal is narrow and rather sharply V-shaped where cut through the upturned Paleozoic limestone at the national-forest boundary.

The scenery at the portals of the Boulder Canyons is most impressive. Weed[8] gives the following description of the main canyon:

> The principal stream draining this alpine area is the Boulder River. Heading in the many lakelets which lie nestled in the mountain basins about Haystack Peak, the stream flows rapidly through a narrow gorge which it has cut through the granites in past glacial times to the point where its volume is augmented by a considerable stream called Bridge Creek. From here northward it flows in a boulder-choked channel through the great canyon of the Boulder, whose glistening walls of polished gneiss rise 3,000 feet high on either side. For the last few miles of its course through this impressive gorge the stream meanders somewhat slowly through a network of channels bordered by dense growths of spruce and fir, with thickets of brushwood, then quietly glides through boggy meadows past the cottonwood-covered islands at the gate of the mountains. Immediately above the Natural Bridge the stream flows in a limestone bed, in which it soon cuts a rapidly deepening gorge as it flows northward in a series of rapids and cascades to disappear in a snowy-white feathery fall of 25 feet into the tunnel of which the Natural Bridge forms the portal. Emerging a hundred yards to the north and 100 feet below, the stream falls into a tranquil pool at the head of a gorge that is a mile or so long and has limestone walls 100 feet high. The roof of the first short tunnel is a dry river bed, the floor of a gorge that is a continuation of the picturesque cutting above the Natural Bridge. The numerous potholes and water-worn ledges show that the river must flow over this channel in time of flood, to fall over a vertical wall into the pool 100 feet below. The beautiful canyon cut in a low limestone anticlinal north of this is, however, immediately deserted by the river, which at once enters a tunnel in the western wall, only to emerge at the northern end of the canyon. That this gorge is occasionally occupied by the river is attested by the driftwood and gravel in its bottom; but the great slopes of talus, where firs 60 feet high are growing, show that such occupancy is but temporary.

The peaks about the head of Elk Creek, as seen from a distance, do not appear to have supported glaciers.

[7] McLeod post office in 1921 was at the junction of the Boulder and West Boulder Rivers, not at the point indicated on the Livingston topographic map.

[8] Weed, W. H., The glaciation of the Yellowstone Valley north of the park: U. S. Geol. Survey Bull. 104, p. 35, 1893.

STILLWATER GLACIER

Calvert[9] mapped areas covered by glacial drift on the Stillwater River and southeastward along the border of the plains to the vicinity of Luther, Carbon County, but he gave no description of the relation of the deposits. Some of these were seen by the present writer in 1921, 1922, and 1924.

A glacier more than 30 miles long occupied the Stillwater Canyon. It extended down the valley to a point near the coal mines about 2½ miles above Beehive, in T. 4 N., R. 16 E., at 5,000 feet above sea level and occupied the basin inclosed by bluffs on the north and east. The moraine, which is marked by very bouldery knolls, extends nearly 3 miles up the Little Rocky Creek Valley, southeast of Nye. The bouldery moraine also extends 1 to 2 miles west of the Nye bridge. Between 4 and 5 miles above this bridge a great ledge of upturned gray limestone, plunging down to the west, extends two-thirds the distance across the canyon from the north side, constricting the floor, and about a mile farther upstream an enormous ledge of igneous rock projects nearly across the canyon floor. These ledges may be remnants of an earlier stage of the canyon cutting, but they were probably entirely overridden by the Wisconsin glaciers. A very stony terrace, with many 3 to 5 foot boulders, extends at least 15 miles down the steep-walled valley below Beehive. It is there about 300 feet lower than No. 2 bench at the top of the south bluff. It is not clear whether this is glacial outwash (a valley train) or a remnant of No. 3 terrace. Apparently the valley was cut within 100 feet of its present depth before the Wisconsin glacier advanced. Moraines of glaciers that occupied gorges at the heads of Fishtail and Fiddler Creeks have not been examined by the writer.

WEST ROSEBUD GLACIER

The great glacier that occupied the West Rosebud Canyon extended about 5 miles down the valley beyond the mountain front, to a point about 2 miles south of the main road. The ice overtopped the high gravelly No. 2 bench on the east and laid upon it a strongly marked lateral moraine. In the last mile the moraine descends the eroded edge of the bench to the valley bottom, about 250 feet below. Two distinct and parallel lateral moraines lie along the great ridge on the west side of the valley, the outer one 100 to 150 feet above the inner one. On these moraines, as high as 300 to 400 feet above the stream, are many granitic boulders 1 to 15 feet in diameter. High in the west face of the ridge at the east side of the valley is a big scarp which, as seen from a distance with field glasses, appears to expose coarse stratified bouldery gravel with an oxidized brownish zone at the top, overlain by the east lateral moraine.

EAST ROSEBUD GLACIER

A similar glacier occupying the East Rosebud Canyon extended northward 3½ miles between the high bench remnants beyond the mountain front and laid a very bouldery terminal moraine across the valley bottom about 2 miles south of Roscoe and 5,400 feet above sea level. Lateral moraines extend southwestward up the valley on both sides. That on the east gradually climbs the slope, forming a spur between which and the main slope is a small coulee. In about a mile the moraine reaches the top of No. 2 bench, 300 feet or more above the main valley bottom. Thence southwestward to the mountain front it lies on the edge of the bench above the steep wooded slope 400 to 500 feet high. (See pl. 47 *A*.) This moraine was evidently formed at the Wisconsin stage of glaciation. Nearly parallel to this and separated from it by the coulee noted above is an outer and older moraine (pl. 47 *B*) extending northeastward on top of No. 2 bench to and about a quarter of a mile beyond the road leading to Luther, where it ends on the smooth flat top of No. 2 bench about 250 feet above the creek. There is no indication, so far as noted, that this moraine ever extended down off the bench into the valley. This outer moraine carries many granitic boulders, some of them 10 to 20 feet in length, but its surface has a more smoothed-down appearance, being not nearly so rough and stony as that of the inner moraine. There is a similar outer lateral on the west side of the valley, but no terminal connects the eroded ends. These relations suggest, if they do not prove, that an earlier (pre-Wisconsin) glacier occupied the East Rosebud Canyon and extended out onto the No. 2 piedmont terrace before the valley was cut much if any below its original top. The relations of the outer moraine are similar to those of the moraines of Blackwelder's "Bull Lake stage" of glaciation in the Wind River Basin, Wyo.

Both East Rosebud and West Rosebud Canyons are profound gorges 3,000 to 4,000 feet or more in depth. In these are numerous beautiful lakes. East Rosebud Lake appears to be due to damming of the valley by a great alluvial fan formed, after the melting of the glacier, by wash from a gorge that breaches the east wall of the canyon. (See pl. 48.) High in the mountains at the head of the West Rosebud Canyon, north of Cooke, are Grasshopper Glacier and several other small existing glaciers.

ROCK CREEK GLACIERS

It is evident from the absence of a terminal moraine outside and from the presence of the ragged edge and pinnacle on the upturned, nearly vertical

[9] Calvert, W. R., Geology of the Upper Stillwater Basin, Stillwater and Carbon Counties, Mont.: U. S. Geol. Survey Bull. 641, pl. 21, 1916.

ledge of limestone known as Point of Rocks, at the mouth of the Rock Creek Canyon, 3 miles above Red Lodge, that no glacier has extended through this portal since the dissection of No. 2 bench. This gravelly bench is beveled across the limestone ledge and extends through the portal at a height fully 300 feet above the valley bottom. There are many large boulders in the lower part of the West Fork Valley and also in the canyon of the main Rock Creek, where great boulder fans lie at the mouths of the gulches. The first suggestion of a terminal moraine was found 2 or 3 miles above the canyon mouth, where there are very bouldery swells about 6,300 feet above sea level but no definite ridge. The profile of the gorge as seen looking upstream from a point near the ranger station certainly suggests modification by a glacier. In the angle between the main stream and Lake Fork above Richel Lodge and the State fish hatchery, about 13 miles above Red Lodge, is a big bouldery moraine 150 to 200 feet high, about 6,700 to 6,900 feet above sea level. If not the outer moraine, this is an inner one formed by the junction of two converging glaciers, 12 to 15 miles long, in the branches of the canyon.

CLARK FORK GLACIERS, WYOMING

Dake[10] states that "the valleys of Line Creek and Bennett Creek, Wyo., near where they emerge from their canyons in the granite onto the plains of the Big Horn River, are occupied by well-marked moraines." About a mile above A. A. Trumbull's ranch on Little Rock Creek is a morainal loop marking the limits of a glacier that extended a short distance outside the canyon mouth. Boulders are so plentiful on the foothills just north of this locality as to suggest the possibility of an older and higher level glaciation.

A great glacier nearly 50 miles in length headed in the mountains north of Cooke, Mont., extended thence down the upper Clark Fork Valley (pl. 13 *C*) and the box canyon cut in its bottom (pl. 25 *A*), and protruded 1 to 2 miles beyond the canyon mouth. About a mile directly east of the portal is a segment of a hogback ridge of upturned Wasatch conglomerate about 1,000 feet in height, one of several forming a north-south strike ridge bordering the mountain front. On emerging from its canyon Clark Fork swings to the southeast and flows through a gap south of this hogback segment. A similar gap traversed by the road at the north end may have been occupied by the stream at an earlier stage. This gap is now blocked by a great bouldery moraine. Emerging from the canyon mouth the glacier advanced until it reached the foot of the hogback and squeezed into the gaps on the north and south. In front of the north-gap moraine is a flat gravelly plain abundantly strewn with large granite boulders (pl. 49 *B*), the derivation of which is discussed on page 41. From this flat plain the front of the remarkably fine moraine rises abruptly about 60 feet. The slopes and broad uneven top (pl. 50) are strewn with granite boulders, many of them 5 to 15 feet in diameter. This moraine is at least 1,000 feet below what was probably the grade of No. 1 bench, or Flaxville Plain, and at least 500 feet below the grade of No. 2 bench. The flat bouldery plain in front of the moraine is probably not a glacial outwash terrace but No. 3 bench and somewhat older than the moraine. It is certain that the glacier of the Wisconsin stage did not advance and deposit this moraine until the box canyon had been cut 1,000 to 1,300 feet into the granitic rocks that underlie the broad bottom of the upper valley. (See pp. 26–27.)

Dake describes moraines on tributaries of upper Clark Fork 10 to 12 miles southwest of the canyon mouth, which seem to him to indicate that ice of the Clark Fork Glacier crossed the main canyon and advanced southward and southwestward several miles up the tributaries Sunlight, Elk, and Dead Indian Creeks. The presence of granitic boulders on these moraines several miles south of the exposed pre-Cambrian crystalline rocks was regarded as evidence that the ice moved up rather than down the valleys in which they lie. The present writer has not seen these moraines; he has observed striations on the granite ledges near and above the north brink of the box canyon at points nearly opposite the mouth of Sunlight Creek. These striae trend parallel to and not southward across the canyon of the main stream.

BIG HORN MOUNTAIN GLACIERS, WYOMING

In the Big Horn Mountains, Wyo., none of the glaciers of the Wisconsin stage, of which there were 17 large ones heading in 70 different cirques on the high central peaks, extended as far as the canyon mouths or reached the plains. The deposits left by these glaciers are described by Salisbury and his assistants.[11]

LATER WISCONSIN STAGE OF KEEWATIN ICE SHEET

ALTAMONT MORAINE IN NORTH DAKOTA

The Altamont moraine of Chamberlin and Upham,[12] which has been regarded as the outermost of the moraines of the Wisconsin stage of the Keewatin ice sheet in the Dakotas, has been traced northward along

[10] Dake, C. L., Glacial features on the south side of Beartooth Plateau, Wyo.: Jour. Geology, vol. 27, p. 128, 1919.

[11] Darton, N. H., Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, pp. 71–91, 1906 (Quaternary system, by R. D. Salisbury and assistants). Darton, N. H., and Salisbury, R. D., U. S. Geol. Survey Geol. Atlas, Bald Mountain-Dayton folio (No. 141), pp. 9–10, 1906; Cloud Peak-Fort McKinney folio (No. 142), pp. 9–12, 1906.

[12] Chamberlin, T. C., Preliminary paper on the terminal moraine of the second glacial epoch: U. S. Geol. Survey Third Ann. Rept., p. 388, 1883. Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, p. 139, 1896.

the Missouri Plateau by Todd, Chamberlin, and others [13] to and across the international boundary near the northwest corner of North Dakota. In 1875 the drift deposits piled along the face and top of the coteau were examined by Dawson.[14] Though recognizing these deposits as composed of drift, Dawson did not regard them as forming a terminal moraine of the continental glacier.

Wood [15] gives some description of the drift deposits in an area including what are now Burke, Mountrail, Renville, and Ward Counties and part of McLean County. The plain of the Souris River east of the coteau in this area ranges in altitude from 1,540 to 1,958 feet. From this the surface rises gradually westward to about 2,250 feet. Wood states that a line drawn from Surrey, on the Great Northern Railway in the eastern part of Ward County, to the prairie level at Stanley, on the Coteau du Missouri, rises from 1,635 to 2,225 feet, or 618 feet. West of Des Lacs there is a rise of 361 feet in 24 miles. The ascent to the hills is in general more abrupt both to the north and to the south than along the Great Northern Railway. The Altamont moraine, which lies along the eastern edge of the plateau in this area, is stated by Wood to range from 15 to 25 miles in width, between limits which have not been very sharply defined. He describes the topography as follows:

No extended observations have ever been made, so far as can be learned, upon the moraine belt of the county. It is generally known as an exceedingly rough area, consisting of knoblike hills interspersed with many sloughs and small lakes. The eastern boundary of the moraine is well marked, as it can be seen 15 miles away, appearing not unlike a great river bluff, except that its upper edge had a more serrate outline. The western limit is much more difficult to assign, because it gradually shades off into the plateau beyond it. Some of the hills are veneered buttes without doubt, but the majority of them, as appears from the railroad cuts, consist of till from bottom to top. The till is not unlike that of the ground moraine, though the per cent of gravel and assorted material is greater in the hills. The varied topographic forms of the terminal moraine are due to deposition, only slightly modified by erosion. Postglacial erosion, mainly in the coulees along the eastern slopes, has drained but few of the multitudes of sloughs.

The roughness of the hills is almost equal to that of the badlands, but the nature of the relief is entirely different. Badland topography is due to erosion; this to deposition. The badlands are characterized by few undrained areas. In this belt the slope of one hill so blends with that of others about it that sloughs, potholes, and lakes are inevitable. As one traverses the area he may pass for miles through a section where all the hills have about the same height, shape, and regularity of arrangement, and then comes suddenly upon a broad amphitheaterlike depression surrounded by a wall of hills, from which there seems to be no exit to the area beyond. Sloughs 100 feet below the average level are not uncommon, and small ones are so numerous that a dozen may be counted from a single hilltop in some parts of the belt. Many of the shallow sloughs are valuable grasslands, sought out by the ranchers, who come several miles to cut the rich marsh grass that grows along their margins.

This morainal belt was crossed by the present writer once in western Burke County, near the west limit of the area described by Wood, and in five different places in Divide County. On these traverses are based the limits shown on Plate 1.

South of Larson, in western Burke County, there is a relief of nearly 400 feet (barometric) between the higher parts of the moraine and the nearly flat plain traversed by the Soo Line and the Great Northern Railway at Larson. The north slope of the coteau, which here trends in a direction somewhat north of west, is considerably cut by ravines, and from its crest there is a very extensive view to the north and east over the broad plain of the Souris River. The higher parts of the moraine in Ts. 160 and 161 N. are very rough. The abrupt bouldery knolls and numerous ponds and marshy depressions make crossing with an automobile difficult where there is not a well-graded road. (See pl. 51 *A*.) The roughness of the moraine also decreases southward from its maximum to the sag traversed by the Grenora branch of the Great Northern Railway from McGregor westward.

The coteau escarpment lowers somewhat toward the west, in R. 96 W., and gives place in R. 97 W. to a broad reentrant in which lies the smooth basin south of Crosby. The morainal features gradually decrease in roughness from the center of the moraine northward, passing into slight sags and gentle undulations near the crest of the marginal slope of the coteau. A small marginal lobe occupied this basin, as the main moraine shifts southwestward from Upland Township (T. 161 N., R. 97 W.) to Frederick Township (T. 160 N., R. 98 W.). This basin may mark the location of the preglacial Yellowstone Valley (p. 58).

West of the reentrant the moraine swings north on the higher ground. Where crossed by the writer, in R. 99 W., southwest of Ambrose, there is a relief of about 400 feet, and then a breadth of about 25 miles southward to the Grenora branch of the Great Northern Railway near Cottonwood Lake. There is continuous and more or less strongly developed morainal topography near the southern border, in T. 159 N. The surface is scored by eroded coulees, and the moraine may here be merging with the earlier belt south of the railway line.

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[13] Chamberlin, T. C., op. cit., p. 398. Willard, D. E., and Erickson, M. B., A survey of the coteaus of the Missouri: North Dakota Agr. Coll. Survey Second Bienn. Rept., pp. 17–27, pl. 3, 1904. Wilder, F. A., Lignite on the Missouri, Heart, and Cannonball Rivers and its relation to irrigation: North Dakota Geol. Survey Third Bienn. Rept., pp. 34–35, 1904.

[14] Dawson, G. M., Report on the geology and resources of the region in the vicinity of the 49th parallel, 387 pp., Montreal, British North American Boundary Commission, 1875; On the superficial geology of the central region of North America: Geol. Soc. London Quart. Jour., vol. 31, p. 614, 1875.

[15] Wood, L. H., Preliminary report on Ward County and adjacent territory with special reference to the lignite: North Dakota Geol. Survey Second Bienn. Rept., p. 84, 1902.

In T. 159 N., R. 100 W., between Rudser and the old Vandalia post office, the headwater tributaries of Little Muddy Creek appear to have been blocked by morainal deposits inclosing some small lakes. They are surrounded by a strong knob and kettle topography.

Where crossed by the writer, in R. 101 W., the moraine mantles big ridges and intervening sags, probably of an old erosion topography. The appearance suggests that the coteau was cut by a preglacial valley and by tributaries discharging northeastward through the sag or reentrant traversed by the Soo Line from Alkabo to Colgan. This may be the position of the outlet of the late Tertiary Missouri Valley described by Bauer.[16]

North of the Soo Line the surface rises rapidly again with a relief of 300 or 400 feet above the plain to the east, reaching an altitude of 2,300 to 2,400 feet or more. From Fortuna, on the railway, the writer went northward diagonally up the long slope, which is much broken by knolls, swells, sags, and ponds of the morainal topography, to the international boundary at 2,337 feet above sea level. From this point there is a very extensive view over the lower plain to the east and southeastward, across the broad reentrant traversed by the railway to the eastward-trending slope of the coteau on the north. Going east 2 miles along the international boundary and thence northward 2 miles into Canada, the writer turned westward and for 7 miles traversed morainal topography, ranging from mild to strong in its development and continuing about 2,300 feet above the sea. The same topography continues south, back into the United States, and west and southwest along the route traversed to the vicinity of Westby. From the highest parts in DeWitt Township (T. 163 N., R. 101 W.) the general altitude decreases westward to a broad sag along the Montana line. Measured northeastward from the vicinity of Westby in a direction at right angles to the general trend of the coteau, the moraine belt has a width of about 25 miles. Many ponds and marshy depressions are interspersed among the ridges, knobs, and low swells such as are characteristic of the unmodified Wisconsin kettle moraine. Boulders are not particularly abundant. They are mostly of granite, but numerous blocks of limestone occur. With these a large percentage of smoothly rounded quartzite pebbles and cobbles are intermingled. These are the same in character as the pebbles of quartzite from the Rocky Mountains which make up the Flaxville gravel on the upland remnants of the Tertiary plains farther west in Montana. Such pebbles were noted by Dawson [17] in the drift along the international boundary as far east as the first crossing of the Souris River. Some quartzite, possibly of the same derivation, was also noted by Dawson as much as 10 miles east of Turtle Mountain.[18] Dawson's description of the coteau and of the morainal deposits where crossed by the 49th parallel [19] seems to be the first if not the only published description of this part of this notable feature. Although he did not interpret the drift deposits here as the terminal moraine of a continental ice sheet, his description is good and may well be cited in this connection:

Where cut somewhat obliquely by this [49th] parallel, the coteau may be said to extend from the 290 to the 335 mile point, a distance of 45 miles. At right angles to its general course, however, its extreme width at this point can not be more than about 30 miles. On approaching it from the east, on the trail from Wood End, which, as already stated, is somewhat more elevated than the prairie lying east of it, a gradual ascent is made, till the edge of the coteau is reached, amounting in a distance of 25 miles to about 150 feet. The country at the same time becomes more distinctly undulating—as on approaching Turtle Mountain from the east—till almost before one is aware of the change the road is winding among a confusion of abruptly rounded and tumultuous hills, which consist entirely of drift material and in many cases seem to be formed almost altogether of boulders and gravel, the finer matter having been to a great extent washed down into the hollows. Where it appears, however, it is not unlike that of the drift of the lower prairies, being yellowish and sandy. Among the hill are basinlike valleys, round or irregular in form and without outlet, which are sometimes dry but generally hold swamps or small lakes, which have frequently been filled in with material washed from the hills so as to become flat-bottomed. The hills and valleys have in general no very determinate direction, but a slight tendency to arrangement in north and south lines was observable in some parts of this region. The hills culminate on the line about the 305-mile point, and westward from this place they are neither so steep nor so stony. The country gradually subsides from its rough and broken character to that of rather boldly undulating prairie, without, however, falling much in general elevation below the tops of the bolder hills farther east. We have, in fact, passed up over the margin of the third great prairie steppe.

The whole of the coteau belt is characterized by the absence of drainage valleys, and in consequence its pools and lakes are very often charged with salts, of which those most abundantly represented are sodic and magnesic sulphates. The saline lakes very generally dry up completely toward the end of the summer and present wide expanses of white efflorescent crystals, which contrast in color with the crimson *Salicornea*, with which they are often fringed. The crystalline crust generally rests on a thick stratum of soft black mud.

The boulders and gravel of the coteau were here observed to be chiefly of Laurentian origin, with, however, a good deal of the usual white limestone and a slight admixture of quartzitic drift. On the western margin some rather large disused stream valleys were seen, holding chains of saline lakes; but their relation to the drift materials of the coteau were not so clearly shown as in other localities farther north.

In passing westward from the last exposures of the Tertiary rocks near Wood End to the locality of their first appear-

[16] Bauer, C. M., A sketch of the late Tertiary history of the upper Missouri River: Jour. Geology, vol. 23, pp. 52–58, 1915.

[17] Dawson, G. M., Report on the geology and resources of the region in the vicinity of the 49th parallel, pp. 228–229, Montreal, British North American Boundary Commission, 1875; On the superficial geology of the central region of North America: Geol. Soc. London Quart. Jour., vol. 31, p. 614, 1875.

[18] Dawson, G. M., op. cit. (report on 49th parallel), p. 225.

[19] Idem, p. 222.

ance within the coteau, a distance of about 70 miles, we rise about 600 feet and attain an elevation of about 2,500 feet above the sea. The slope of the surface of the Lignite Tertiary, then, assuming it to be uniform, is a little less than 100 feet per mile; and on and against this gently inclined plane the immense drift deposits of the coteau hills are piled.

ALTAMONT MORAINE IN MONTANA AND SASKATCHEWAN

From the Montana-North Dakota State line south of Westby the south border of the morainal belt continues fairly well defined westward. Beekly[20] describes this belt as follows:

The flat central part of the field gradually merges on the north and east into a region of more or less prominent hills and ridges separated by cuplike and troughlike depressions. Toward the north these hills and ridges are smaller and more closely huddled together and continue so beyond the northern limit of the field [the international boundary]. Practically all the forms characteristic of morainal topography are represented in the surface of this area, which though comparatively rough contains few hills or ridges rising more than 200 to 300 feet above the lowest depressions. The entire surface is grass covered. Glacial boulders ranging in size from a few inches to several feet in diameter are more or less thickly scattered over the well-rounded tops of the hills and ridges. No precipitous bluffs or steep valley walls, affording exposures of the rocks underlying the glacial material, occur in this part of the field. * * *

No opportunity is offered for measurement of the drift, but its general appearance and the topographic forms here present seem to indicate that the maximum thickness is between 100 and 200 feet. The glacial material consists of silty boulder clay containing, in addition to sand and gravel, a great many angular fragments and boulders of limestone and various igneous rocks. The boulders, which are usually somewhat worn, range in size from coarse pebbles to rocks weighing a ton or more. They are thickly scattered over a large part of the surface and were used as criteria for mapping the boundary of glacial material.

Many exposures of the drift are now afforded by the cuts along the Soo Line in the vicinity of Raymond. The traverses made by the present writer in 1916 and 1920 seem to indicate that the southwest border of the main belt passes northwestward across the boundary north of Comertown, in R. 56 E., but that two more or less well-defined branches lie farther west, one crossing the international boundary north of Raymond, in R. 54 E., and another reaching the valley of Big Muddy Creek just south of the boundary, in R. 52 E. Altitudes along the boundary range from 2,200 feet at and near the northeast corner of Montana to 2,385 feet about 10 miles farther west, toward Big Muddy Creek.

The moraine that runs northwestward from Dooley is strongly marked north of Raymond, in the northeastern part of T. 37 N., R. 54 E. West of this locality is a smoother tract, and beyond is the outermost branch of the moraine, which is lost in the sharply dissected tract bordering the Big Muddy Valley. The configuration of this great moraine through a belt 50 miles long and 2 miles wide bordering the international boundary is shown on sheets 38, 39, and 40 of topographic maps of the international boundary.

Numerous reconnaissance trips were made northward near and west of the Big Muddy Valley as far as the southern lines of the Canadian National Railways and the Canadian Pacific Railway—that is, to Bengough, Viceroy, Vantage, and other points farther west in Saskatchewan, in an attempt to determine whether or not the great terminal moraine of the later Wisconsin ice sheet passed westward around the Wood Mountain upland. As a result of these trips it was concluded that what has been called the Altamont moraine in northwestern North Dakota, which there marks the limit of advance of the later Wisconsin ice sheet, probably continues northwestward in southern Saskatchewan, mostly on the east side of the great through valley, 100 to 300 feet deep, in which lie Lake of the Rivers, Willowbunch Lake, and Big Muddy Lake, and which is continuous southward as the Big Muddy Valley through Sheridan and Roosevelt Counties, Mont., to the Missouri River. This valley was evidently a very important outlet for drainage while the ice front stood at the Altamont moraine. Not only did it carry drainage from the ice front from regions far to the north, but all the water from the South Saskatchewan River and its tributaries west of the ice front, and possibly also from the North Saskatchewan River, was diverted through this valley to the Missouri River. Where it crosses the international boundary the Big Muddy Valley has a width of about a mile and a depth of about 300 feet.

What may be a part of the Altamont moraine lies on both sides of the high divide between Big Muddy Lake and the heads of Beaver Creek, in Saskatchewan. Near the south line of T. 3 N., R. 24 W., the south front of the moraine is very well defined, being marked by a hummocky, boulder-strewn ridge (pl. 51 *B*) which is in marked contrast with the smooth, gently sloping plain to the south. In 1916 a morainal belt was seen by the writer between Bengough and Viceroy. This belt is said to continue southeastward and may connect with either the main Altamont moraine or one of the branches seen near the international boundary east of the Big Muddy Valley. It is also well marked on the ridge north of Viceroy. On going west and north past the south end of Lake of the Rivers, the writer encountered what may be the same moraine southeast of Vantage, in T. 10 N., R. 1 W., near the Assiniboia branch of the Canadian Pacific Railway. It is probably crossed by the Gravelbourg branch of the Canadian National Railways near Ettington and may extend thence northwestward, though it was not seen again by the writer.

[20] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, pp. 323, 326, 1912.

With the recession of the ice front from the Altamont moraine the glacial history of this part of the northern Great Plains ended, and conditions graded into those of Recent time.

LATE PLEISTOCENE OR RECENT UPLIFT

There is no very definite evidence that uplift occurred in this region in connection with or since the Wisconsin stage of glaciation. Almost everywhere the streams appear to be actively cutting downward. The depths of post-Wisconsin erosion range from 50 feet or less to 100 feet or more on the plains, and some of the mountain canyons, as on the Sun River, have narrow tortuous gorges cut to depths of 100 to 200 feet in their bottoms. The Milk River is wandering about and tying itself in bowknots on a valley fill because it can not cut down faster than the Missouri, to which it is tributary. The Missouri cut across cols west of the Milk River after its relocation that followed the pre-Wisconsin (Illinoian or Iowan?) stage of glaciation, and it has cut a great trench in shale and sandstone 100 to 500 feet in depth, but how much of this has been cut in post-Wisconsin time is not evident. Below the city of Great Falls the Missouri plunges over a series of cascades and rapids, descending 612 feet in 12 miles of its new course. (See pl. 31 *B*.) Above the city it is meandering on a valley fill. It is not certain just how much of this depth of erosion has occurred since the early Wisconsin glaciation, inasmuch as the ice sheet of that stage is not known to have crossed or diverted the river. Taken altogether, the streams certainly have not yet had time to reach the limit of downcutting and do any considerable amount of lateral planation since the last regional uplift.

There are certain facts which are not clearly evaluated but which suggest that a differential regional uplift with easterly or northeasterly downward tilt has occurred since the early Wisconsin ice invasion, if not since that of later Wisconsin time. There is a gradual westerly increase in the present altitudes of points west of Minnesota that were just high enough to stop the advance of the Wisconsin ice front. These facts are cited below for consideration for what they are worth. It is quite possible that there are in some places, if not in all, modifying factors that should be taken into consideration for their true interpretation.

1. The altitude at the head of the Coteau des Prairies, the great wedge that separated the Des Moines lobe from the Dakota lobe of the Keewatin ice, is about 2,000 to 2,100 feet in northeastern South Dakota.

2. A few miles north of the line between North Dakota and South Dakota, on the west side of the Dakota lobe, the ice front reached altitudes which are now 2,100 to 2,200 feet and then stopped on top of the Coteau du Missouri, forming a reentrant south of which on the lower ground it advanced 60 miles farther west.

3. Near Stanley, where the margin of the early Wisconsin drift swings west on top of the coteau in northwestern North Dakota, the altitude is about 2,260 feet. Higher points on the coteau reached by the later Wisconsin ice stand at 2,300 to 2,400 feet or more, but the ice did not extend much beyond them.

4. On the Flaxville Plain near Opheim, in northeastern Montana, where there was probably the head of a great reentrant in the early Wisconsin ice margin, barometric readings indicate an altitude of 3,200 to 3,300 feet.

5. At the north side of the Little Rocky Mountains the limit of the early Wisconsin drift on high remnants of the Flaxville Plain near Lodgepole is 3,500 feet.

6. Northeast of Choteau the west limit of the advance is about 3,800 feet.

7. North of Cut Bank the points that caused reentrants 8 or 10 miles deep in the ice margin now stand 4,200 to 4,400 feet above sea level.

Were these several altitudes west of Minnesota those of the shore line of a great lake or sea they would certainly be regarded as indicating subsequent tilting of the land. Although such an explanation is not so strictly applicable to the edge of an ice sheet, the present westerly increase in these altitudes is worthy of consideration as suggesting, if not proving, that such tilting with uplift of the mountain belts has occurred since early Wisconsin time. Any inferences regarding regional tilting that may be drawn from the above data must also be checked with the results of studies by Upham, Tyrrell, Dowling, McInness, and Johnston of the southward tilting of beaches of Lake Agassiz during and since the retreat of the fronts of the ice sheets of the Wisconsin stage.

Postglacial marine deposits are reported as found at altitudes of 500 to 600 feet in the valleys draining to the south and west shores of Hudson Bay. In this connection it may be noted that any southerly tilt or reduction of northward slope of the land between Hudson Bay and southeastern South Dakota subsequent to the southward diversion of the Missouri River through the Dakotas, especially if it occurred at about the same time as uplift of the plains and mountains of Montana and Wyoming, would tend to accelerate cutting along the Missouri and the Yellowstone and all their tributaries. Uplift in the Hudson Bay region, however, must have tended to retard erosion on the Red, Nelson, and Saskatchewan Rivers. Whether or not there is evidence of any such retardation on those streams is not discussed in the present paper.

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