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ILLUSTRATIONS.

PHOTOGRAPH BY N. H. DARTON.

CLIFF OF CHUGWATER RED BEDS ON NO WOOD CREEK AT THE MOUTH OF TENSLEEP CREEK.

GEOLOGY OF THE BIGHORN MOUNTAINS.

By N. H. Darton.

INTRODUCTION.

This report is the result of studies made in the field during the seasons of 1901, 1902, 1903, 1904, and 1905. It relates to an area of about 9,000 square miles, situated mainly in the north-central portion of Wyoming and extending northward into Montana. Its location and general surroundings are shown on Pl. II. It covers tne greater portion of the Bighorn uplift, together with an adjoining area of the Great Plains on the east. It also includes a small part of the Bighorn Basin and the eastern end of the Bridger Range. The report describes the various rocks, their structure, history, and mineral resources, including underground water, coal, gypsum, and various other products. It also contains information as to surface waters available for irrigation.

Throughout the work assistance has been rendered by Mr. C. A. Fisher, who mapped portions of the area, measured numerous sections, collected fossils, and examined most of the crystalline rocks; and the author is indebted to Mr. Albert Johannsen for some of the petrographic descriptions.

Previous observers have given but little information regarding the geology of the Bighorn Mountains, though Dr. F. V. Hayden ascertained the general relations of the uplift in his exploration of the Northwest, and Mr. George H. Eldridge, who crossed the range near Bald Mountain and southwest of Buffalo during the summer of 1893, described[a] some of the broader features of the geologic succession and structure in a remarkably comprehensive manner, considering how small an area he had the opportunity to examine. The Bighorn region is very thinly settled, there being no permanent habitations among the mountains, and it is but little visited by others than hunters, prospectors, and herders. There have recently been established two summer resorts in the mountains, and each year a larger number of persons visit the region. Unfortunately the mineral prospects have proved disappointing to the prospectors, and there appears to be but little promise that the area will become important on account of its mineral resources. In the Bridger uplift promising prospects of gold and copper have recently been discovered, which may prove of value.

[a] Eldridge, G. H., A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894.

There are extensive forests in the mountains, which are now included in a Government forest reserve, but their timber is not of great value. Much of the area below timber line contains an abundance of luxuriant grasses and other plants, which afford excellent pasturage for stock, and large herds of sheep and cattle are ranged in the region during the short summer season. Game is moderately abundant, and most of the streams contain large numbers of trout. The region is one of great interest geologically on account of its variety of sedimentary rocks, interesting structure, and remarkably instructive glacial features. The central area, with its high peaks, presents alpine scenery of notable character. Doubtless in the future the region will be extensively visited by tourists, hunters, and geologists.

GEOGRAPHY.

General features.—The Bighorn Mountains are an outlying portion of the Rocky Mountains, extending from north-central Wyoming into the south-central portion of Montana. They rise out of the Great Plains, which have an altitude of 4,000 to 5,000 feet, to altitudes which vary from 10,000 to slightly over 13,000 feet in the higher mountain summits. The portion of the range to which the term Bighorn Mountains is applied trends north-northwest in the northern portion of its course and nearly due north and south in the southern central portion, and east and west where it joins a high east-west range known as Bridger Range and Owl Creek Mountains.

The Bighorn Mountains end in the north at the canyon of the Bighorn River, north of which the same uplift is continued in the Pryor Mountains, a range of moderate elevation which extends but a short distance. West of the Bighorn Mountains there is a wide area of plains known as the Bighorn Basin, which extends to the foot of the Shoshone Mountains on the west and the Bridger Range and Owl Creek Mountains on the south. Where it is traversed by the Bighorn River, in Montana, the altitude is about 3,600 feet. The Bighorn Mountains rise abruptly from the plains, though they are flanked by several lines of low hogback ridges. The salient features are the central region of high ridges of granite, the front range of sedimentary rocks, and the summit plateaus at the northern and near the southern ends of the uplift.

Central area.—The central area of the higher portion of the Bighorn Mountains is a region of rugged ridges rising toward the main divide along the center of the uplift. In the portion of this divide which lies between the headwaters of Piney and Goose creeks on the east and Paintrock, Shell, and Tensleep creeks on the west the granite ridges rise in a cluster of high mountains, culminating in Cloud Peak, which has an altitude of 13,163 feet. A view of this peak is given in Pl. VIII, *A*, p. 18.

In this high area the ridges rise from 3,000 to 4,000 feet above the valleys, and the general configuration is very rugged, presenting some of the boldest alpine scenery in the country. There are many precipices over 1,000 feet high, especially about the cirques among the higher summits. Several of these cirques contain glaciers, one of which, on the east side of Cloud Peak, has a length of nearly a half mile. Extensive snow banks remain all summer in many of the higher portions of the range. The drainage of this area is peripheral and in the main direct. The divide and its numerous branch ridges present serrated outlines and at some points are crossed by deep wind gaps. The higher portions of this central area exhibit strong erosion, due largely to the intensity of frost action, the steep declivity, and the abundance of water to carry off the débris. The topography is youthful and the granite floor on which the sedimentary rocks were deposited has been entirely cut away by erosion, so that its configuration can only be surmised. The higher region has been extensively glaciated, most of its topographic features being characteristic of glacial erosion. The most marked of these are the many deep cirques, cut back to or nearly to the main divide. Accumulations of glacial deposits occur in the lower valleys of the central area, impeding the drainage and giving rise to many small lakes. Other lakes occur in rock basins excavated in granite in connection with glaciation.

The timber line is at an altitude of about 10,000 feet, above which the surface consists mainly of rock masses in part disrupted from their original ledges. Many of the steeper slopes consist of talus of huge granite blocks. (See Pl. XXX, *A*.)

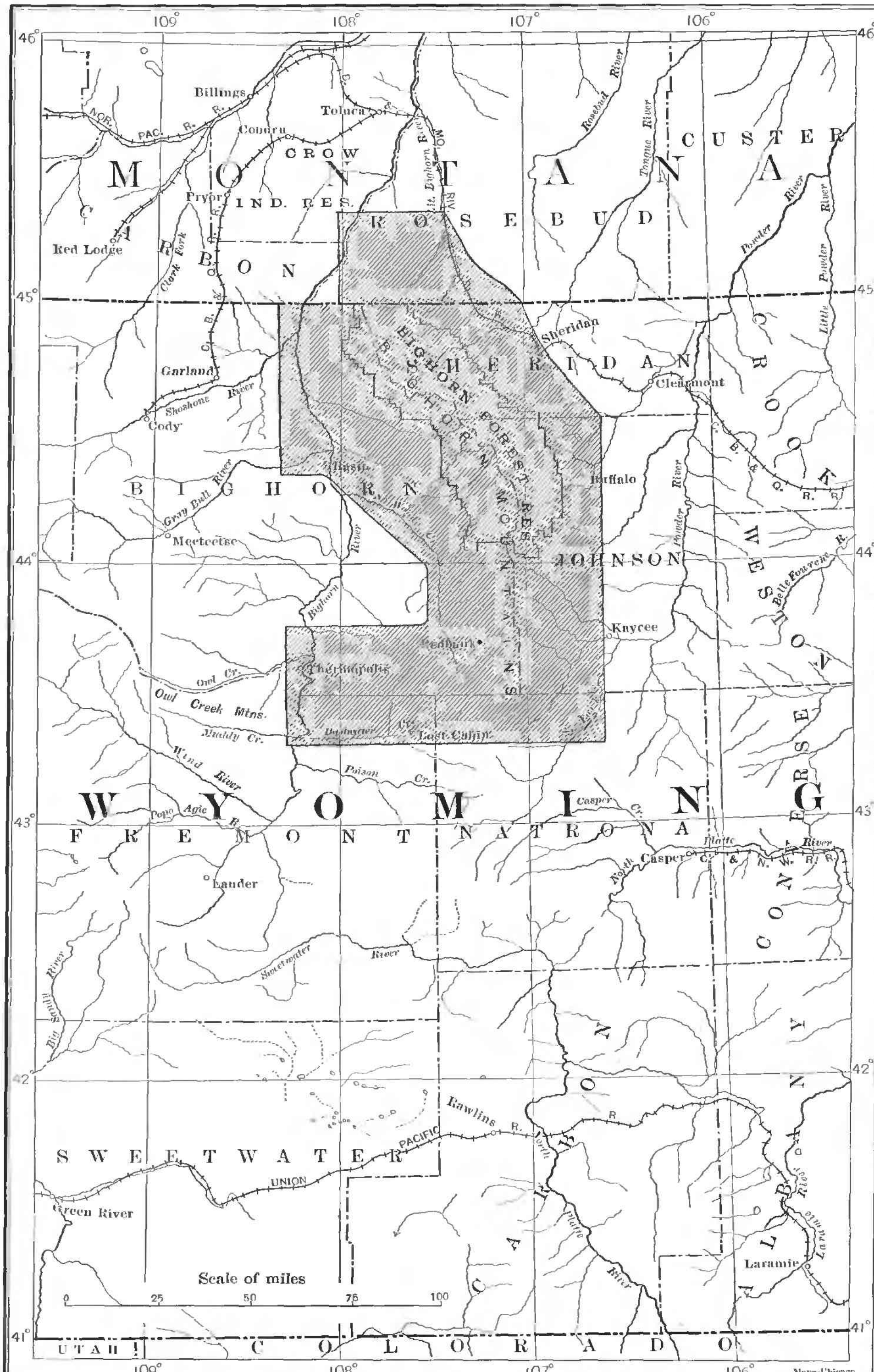
Central plateau.—The sedimentary rocks arch over the northern and south-central portions of the Bighorn Mountains, forming an elevated plateau which has an altitude of about 9,000 feet in the north and 8,000 feet in the south. It presents broad areas of tabular surfaces, especially near the divides, but is deeply trenched by numerous canyons, the most notable of which are those of Little Bighorn, Bighorn, and Tongue rivers. Much of the plateau surface is covered by forests interspersed with parks, which are extensively used as grazing grounds for cattle and sheep during the short summer season. Portions of the plateau also extend northward and southward, partly encompassing the central granite area and the granite area at the southern termination of the uplift.

Front range.—Along the sides of the Bighorn Mountains there are steep slopes to the plains on the east and the Bighorn Basin on the west. In some districts the central plateau terminates in high cliffs, but in other areas, especially along the eastern side of the range, there is a distinct flanking ridge of "rim rock" rising slightly above an inner valley but sloping steeply toward the plains. West of Sheridan and Buffalo this front range presents an imposing line of mountain slopes extending southeast and south and usually rising 2,000 feet above the plains. (See Pl. XXXIX, *A*.) It is composed of sedimentary rocks dipping steeply to the northeast and east, and it usually presents to the west a high cliff of limestone. Through this front range the creeks and rivers which rise in the central area find their way out to the plains in canyons, some having walls nearly 2,000 feet high. The most notable are those of the Little Bighorn and Tongue rivers on the east side of the range and Shell, Paintrock, and Tensleep creeks on the west side. Bighorn River flows in a deep canyon across the northern end of the range and terminates the mountains to which the name Bighorn applies. This river, in its upper portion, cuts also across the western end of the Bridger Range, separating it from the Owl Creek Mountains. Toward the southern end of the mountains the front range on the east side has long, gentle slopes, and the central plateau presents a high escarpment to the west.

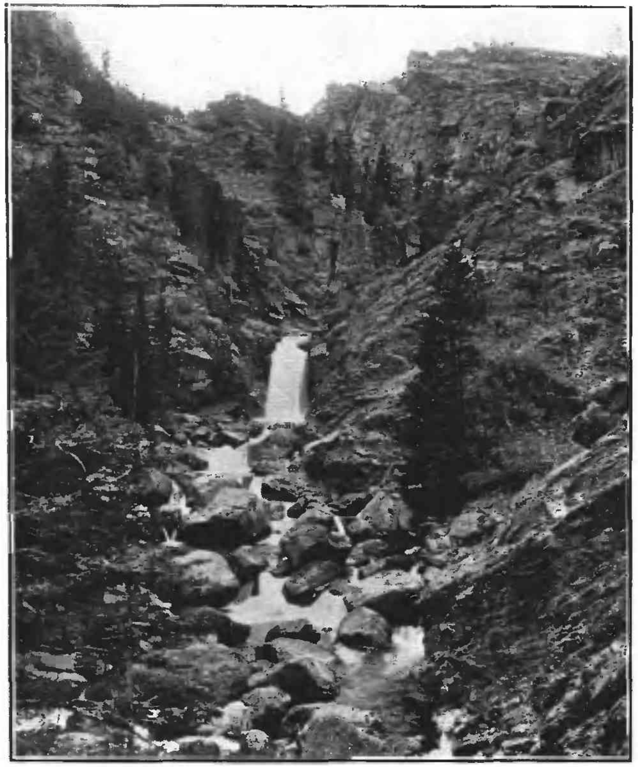
Red wall.—In most portions of the Bighorn uplift the red wall is a prominent feature. It extends along the foot of the mountain slopes and often has a height of 400 feet. It is due to the outcrop of the moderately hard red sandstone which constitutes the greater part of the Chugwater formation. A typical view of this wall is given in Pl. I. The red wall extends continuously for many miles from Red Fork of Powder River past Barnum and along the east side of the valley of Buffalo Creek to the southern termination of the Bighorn uplift. East of Houck's it is deflected to the east for some distance and partly broken into outlying buttes, but elsewhere it presents a high, even-crested wall of red beds facing west and northwest and rising from 300 to 500 feet above a red valley which separates it from the long mountain slopes to the west. The red wall also extends north from Red Fork up the valley of the North Fork of Powder River. Owing to the steepness of the dips of beds along the east side of the mountain northward it is not a conspicuous feature in the region southwest and northwest of Buffalo and Sheridan, but it appears again in the portion of the uplift in Montana. In the vicinity of Shell and southward the wall is prominent for many miles, especially in the vicinity of Hyattville, Tensleep, Rome, and Redbank. It is also well developed on the west side of the valley of No Wood for several miles north and south from No Wood post-office. The wall reappears on the northern side of the Bridger uplift, especially along Buffalo Creek southeast of Thermopolis, where it is 250 to 350 feet in height.

Hogback ranges.—Extending along the foot of the Bighorn Mountains on either side is usually a series of hogback ranges, which appear very insignificant in comparison with the great mountain slopes that they flank. They are due to the outcrop of sandstones of moderate hardness and they rise only from 100 to 400 feet above the adjoining valleys. The first of these valleys marks the outcrop of the lower red beds extending along the foot of the mountains, and, owing to the steep dip of these beds and their relative hardness, their valley usually is not so distinct as in the Black Hills and some other regions. The red wall often constitutes the inner face of the hogback range. The hogback rim is crossed by numerous valleys or canyons, which divide it into level-topped ridges of various lengths. In many places along the eastern side of the mountains these ridges are covered by or merge into terraces covered by deposits of gravels and sands, extending from the foot of the mountains.

Drainage.—From the higher portion of the Bighorn Mountains flow many large streams, those on the northeastern side draining into branches of Tongue River, mainly through Crazy Woman, Clear, Piney, and Big Goose creeks, while the southeastern side is drained by several forks and branches of Powder River. Down the west slopes flow branches of Tensleep, Paintrock, Shell, Otter, No Wood, and other creeks which cross the east side of the Bighorn Basin and empty into Bighorn River. This stream, after traversing the Bighorn Basin from south to north, turns northeastward and crosses the northern end of the Bighorn Mountains, finally flowing into the Yellowstone in southeastern Montana. One of its larger branches, Little Bighorn River, drains a portion of the plateau on the east side of the Bighorn Mountains near the Montana line and flows out of the mountains in a canyon whose walls are over 2,000 feet high. The southern end of the mountain is drained by Badwater Creek and its main branch, Bridger Creek, which crosses



MAP OF PORTION OF WYOMING, SHOWING AREA TREATED.

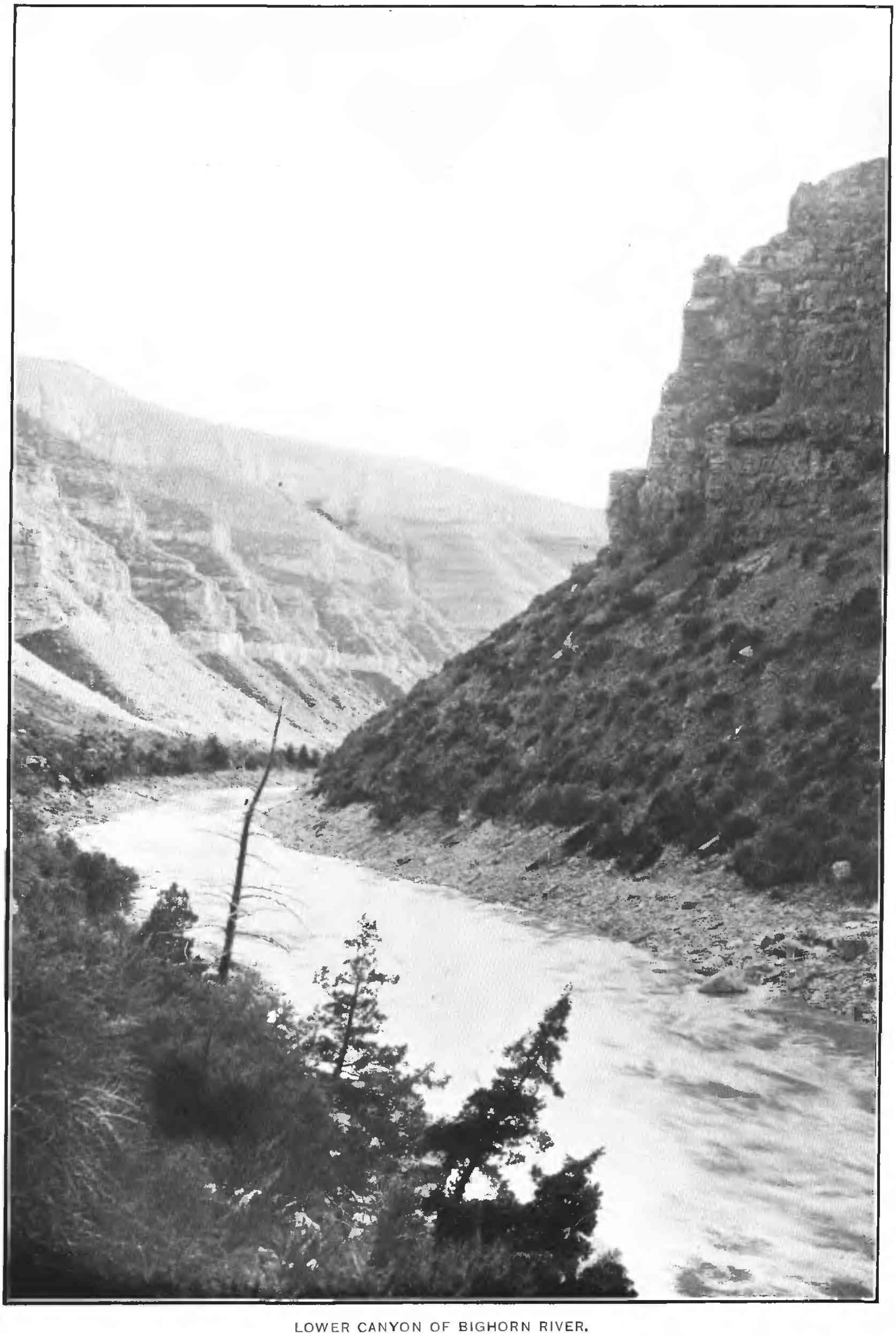


A. FALLS OF BIG GOOSE CREEK.

In gorge in the granite high on east side of Bighorn Mountains. Looking west.
Photograph by J. Stimson.

B. GRANITE SLOPE RISING ABOVE THE VALLEY OF DEADWOOD SHALE.

Rapid Creek, east side of Bighorn Mountains; looking southwest. Shows steep rise of the granite, causing rapids in the stream.



LOWER CANYON OF BIGHORN RIVER.

View across axis of Bighorn uplift. Cliffs of Madison limestone. Photograph by J. Stimson.

the western end of the uplift. Bridger Range is drained on the south by branches of Badwater and on the north by Kirby and Buffalo creeks, all affluents of Bighorn River. This river crosses the west end of the range in a canyon with walls over 2,500 feet deep, separating it from the Owl Creek Mountains.

GEOLOGY.

DESCRIPTION OF THE ROCKS.

GENERAL FEATURES.

The Bighorn Mountains are a great anticline due to an uplift of many thousand feet, which has brought a thick series of Paleozoic and Mesozoic sedimentary rocks high above the adjoining Great Plains. Owing to the deep erosion of the crest of this uplift, the mountains present a central nucleus of pre-Cambrian granites, with the sedimentary rocks on the flanking front ranges and constituting the plateaus at either end. The region is one of exceptionally fine exposures, which afford a rare opportunity for study of stratigraphic relations and variations. Most of the rocks are hard, and streams flowing out of the central mountain area have cut deep canyons and gorges, in whose walls the formations are often extensively exhibited. The structure presented locally is usually that of a monocline dipping toward the plains on the east and south sides and the Bighorn Basin on the west and north. The oldest sedimentary rocks usually are at the base of a ridge facing the granite area, and each higher stratum passes beneath a later one in regular succession outward toward the margin of the uplift. In Pl. XXXVIII are given cross sections showing the general structural relations of the rocks. In this illustration it will be seen that the sedimentary formations consist of a series of thick sheets of sandstone, limestone, and shales, all essentially conformable in structure, although lacking some members of the geologic succession. Remnants of supposed Tertiary deposits occur on the higher slopes and flank portions of the southern extension of the range. Quaternary deposits of glacial origin lie on the granites in the highlands, and fluviatile gravels and sands are on terraces overlapping the older sedimentary rocks on the plains. The stratigraphy presents much similarity to the succession of rocks in the Rocky Mountains of Colorado and Wyoming, and in the Black Hills, but it has numerous distinctive local features. Following is a list of the formations exhibited in the uplift, with a generalized statement as to thickness, characteristics, and age:

Generalized section in the Bighorn Mountains.

Formation.	Character.	Average. thickness.	Age.
		Feet.	
De Smet formation	Gray sandstones and carbonaceous shales with lignite deposits.	+ 5,000	Upper Cretaceous (and Eocene?).
Kingsbury conglomerate.	Conglomerate	0- 2,500	Upper Cretaceous.
Piney formation	Gray and brown sandstone and shales	2,000- 3,000	Do.
Parkman sandstone	Soft massive buff sandstone with harder, darker concretions.	300- 500	Do.
Pierre shale	Dark-gray shale with concretions	1,200- 3,500	Do.
Colorado formation	Gray shales, thin brown sandstones below; hard fine gray sandstones (Mowry beds) in middle. Concretions with *Prionocyclus*, etc., near top.	1,250- 1,500	Do.

Generalized section in the Bighorn Mountains—Continued.

Formation.	Character.	Average thickness.	Age.
		Feet.	
Cloverly formation	Coarse massive buff sandstone below, with light-colored shales and some sandstone above.	80- 200	Upper and Lower Cretaceous (Dakota-Fuson-Lakota).
Morrison formation	Massive shale, greenish-gray, buff, and maroon, with thin sandstones.	150- 300	Lower Cretaceous (?).
Sundance formation	Soft sandstones overlain by greenish-gray shales. Several hard fossiliferous layers near top and bottom.	250- 450	Jurassic.
Chugwater formation	Red shales and soft sandstone, thin limestone layers near top and bottom, and gypsum deposits.	700- 1,300	Triassic (?) and Permian.
Embar formation	Gray limestone with cherty beds	0- 250	Carboniferous (Pennsylvanian).
Tensleep sandstone	Massive buff to gray sandstone, calcareous near top	30- 150	Do.
Amsden formation	Red shales or sandstone at base, overlain by fine-grained white limestone. Cherty near top.	200- 350	Carboniferous (Pennsylvanian and Mississippian?).
Madison limestone	Light-colored limestones, very massive near top	250- 1,100	Carboniferous (Mississippian).
Bighorn limestone	Mostly hard, massive limestones with streaks of silica, overlain by series of softer, purer limestones with local shaly limestone; 3 to 30 feet white sandstone at base to eastward.	0- 300	Ordovician (lower members Trenton, upper member Richmond).
Deadwood formation	*Feet.* Slabby limestones with flat-pebble limestone conglomerates, sandy to southeast ... 0-200 Green shale with sandstone layers ... 300-600 Massive brown sandstones ... 0-400	900- 1,150	Middle Cambrian.
Granite	Gray and red of various kinds, penetrated by diabase and other dikes.		Archean or Algonkian.

The granites are mostly red and massive and constitute a floor for sediments of middle Cambrian age. These Cambrian rocks are sandstones, shales, and limestones nearly a thousand feet thick, and apparently they do not include sediments of upper Cambrian age. The Ordovician is represented mainly by a massive limestone of Trenton age, and its top member contains a Richmond fauna, there being a hiatus between the two. The Silurian and Devonian are absent. The Carboniferous presents about 1,500 feet of beds, partly of the Mississippian series, but extending up into the Pennsylvanian, which ends in a persistent sandstone member to the north and a limestone to the southwest, ordinarily constituting the lower outer slope of the limestone front range. Next follow the red beds, which extend around the foot of the mountains, as in the Black Hills and other uplifts of the Rocky Mountain province. They attain a thickness of over a thousand feet and are either all of Permian age or in part Triassic. The marine Jurassic, which follows, is similar to that of the Black Hills and of southeastern Wyoming, and contains an abundant middle to upper Jurassic fauna. It is overlain by the Morrison shales, only about 200 feet thick, but remarkably persistent in the Rocky Mountain province. Representatives of the "Dakota" sandstone appear in the Bighorn uplift, but with greatly diminished development as compared with the Black Hills and other regions southward. The hard sandstone supposed to represent the Lakota formation is the most conspicuous feature. The great series of upper Cretaceous shales attains a thickness of over 4,000 feet in the plains adjoining the Bighorn Mountains. At the base is the Benton group, in which, however, the middle limestone member (Greenhorn) is not characterized. The Niobrara also lacks the chalky element which is so conspicuous in the region to the south, and presents no paleontologic evidence of its existence. Its presence is indicated, however, by the apparently unbroken sedimentation from the Benton to the Pierre. The latter has a thickness of from 2,000 to over 3,000 feet near the Bighorn Mountains and presents the usual monotonous succession of gray shales with fossil-bearing concretions. It is terminated by a sandstone supposed to represent the Fox Hills, which, in turn, is succeeded by a great development of fresh-water deposits including representatives of the Laramie. The latter occupy a wide area between the Bighorn Mountains and the Black Hills, and also a large syncline in the Bighorn Basin. They consist of the usual succession of sandstone and shales, with numerous beds of lignite, but along part of the eastern side of the range there are extensive deposits of conglomerate near the base, consisting of local materials, which indicate early Laramie uplift and erosion. The Tertiary is not well represented in the greater part of Bighorn uplift. In the basin to the west are thick deposits of the Wasatch, and along the south end of the range there is overlap of Bridger formation, but in the mountains there evidently was extensive uplift and denudation in Tertiary times. Some small remnants of supposed Tertiary deposits have been found high up in the range, but their identity is not established. The Quaternary deposits consist of numerous high terraces and old alluvial fans along the lower slopes of the mountains, glacial drift, and the alluvial plains along the streams, which merge into flood plains of the present period. The higher portions of the Bighorn Mountains have been extensively glaciated. There were two principal epochs of ice advance, and small remnants of glaciers are still found near some of the higher summits.

The principal features of stratigraphic variation in the Bighorn uplift are shown on Pl. VI. It will be seen that these features are uniform over wide areas, but there are local variations in thickness. Certain local variations of stratigraphy are pointed out in the detailed descriptions of the individual formations. In the latter part of this report the sequence of events attending the deposition of these formations will be discussed.

PRE-CAMBRIAN ROCKS.

GRANITE.

OCCURRENCE.

The exposure of granite in the northern central portion of the Bighorn uplift occupies an area of about 1,200 square miles. Its form is elliptical, extending about 62 miles north-northwest and south-southeast and having its greatest breadth, about 30 miles near Cloud Peak. To the north and south, as well as on the sides, the granite passes beneath the sandstone at the base of the Deadwood formation. In a few localities its boundary is defined by fault lines, along which it is brought into contact with various formations. The most marked irregularity in its boundary line is its westward extension down the canyons of Shell and Granite creeks. To the northwest it reappears again in the center of the uplift in an irregular, narrow zone extending from the foot of Hunt Mountain past Bald Mountain nearly to the Montana line. A small exposure appears in the crest of the anticline in the middle of the range near Point Lookout in Montana, and in the anticline of Dry Fork Ridge, where it is crossed by the canyon of Little Bighorn River. In the northern areas the surface is largely a platform from which the overlying Deadwood beds have only recently been removed, but in the wide central area to the south it rises far above the sedimentary rim rocks of the front ridge into rugged mountains which have long been subjected to erosion. In some of the valleys of this central region it is hidden beneath glacial deposits, and on a small portion of the main divide near the head of Powder River it is covered by beds of supposed Tertiary age. In most of the mountain area, however, it presents continuous outcrops of bare rock ledges, which in the higher regions are generally broken into huge masses that cover most of the surface above timber line. At frequent intervals the granite is traversed by dikes, mostly of diabase, which vary from a few feet to 200 feet in width.

In the southern portion of the Bighorn Mountains the granites appear along the fault northeast of Bigtrails, and in an area of about 100 square miles near the southern end of the mountains, due to local increase in the amount of uplift. The latter area is in an elevated region along the upper portions of Badwater, Clear, Lonetree, Lost, Deep, and Trout creeks and West Fork of Powder River.

In the Bridger uplift the pre-Cambrian rocks occupy an area of about 65 square miles, constituting the high central summits and the long, rugged southern slopes. They also are exposed by deep erosion in the upper canyon of Bighorn River at the west end of the Bridger Range.

CHARACTER AND DISTRIBUTION.

The granites consist largely of two varieties—a moderately coarse-grained red granite and a medium to fine grained gray granite, which merge into each other so gradually that they are believed to be part of the same magma. Local areas of white, aplitic granite appear, gneissic granite is developed in some regions, and small streaks and masses of hornblendic rocks occur occasionally. Gray granite of several varieties occupies the largest outcrop area, including the higher part of the central range, and lies mostly in one great mass with indefinite boundaries at its margin. In the northern portion of the granite area and along parts of its west side red granite predominates, but within the general area of each variety the other sometimes appears locally. The northern boundary of the great central area of gray granite crosses the main divide at the head of South Fork of Tongue River, extends southeastward south of Dome Lake to Finger Rock, and then passes northeast to the overlap of sedimentary rocks at the mouth of Tepee Creek. An outlying area extends along the northeastern boundary of the crystalline rock area from Rapid Creek to Horse Creek beyond Tongue River, including Walker and Black mountains. A small area lies 3 miles northeast of Dome Lake. Thes western margin passes along the west slope of the main divide south from the head of South Fork of Tongue River to nearly opposite Cloud Peak, and is separated from the sedimentary rocks on the west by a wide zone of red granite. In the southern and eastern part of the central area gray granite predominates.

The rock is mostly of light-gray color, moderately coarse grain, and massive structure, although on close examination it exhibits an incipient tendency toward schistosity, a feature which is often brought out more conspicuously by weathering. Some portions are extensively jointed, usually with vertical as well as transverse jointing, which often gives rise to slabs or rectangular blocks with sharp edges. In general its outcrops are much more jagged than those of the red granite. In the granite area on Tongue River the rock is very dark and weathers into rough, jagged surfaces. The deep canyon shown on Pl. VII is cut in this material. Black Mountain consists of typical gray granite. Nearly all of the higher mountain mass constituting the main divide between the heads of Goose and Canyon creeks consists of a coarse-grained massive granite of great hardness and medium to dark gray in color.

The red granite is a conspicuous feature in the northern portion of the main crystalline rock area, extending entirely across it from west of South Fork of Tongue River to the mouth of Tepee Creek and to its northwest corner. It also extends far southward along the western side of the area, appearing extensively along the branches of Medicine Lodge, Trapper, and Paintrock creeks, and is the principal variety in the Bald Mountain region. It has a light-grayish appearance at a distance, but on closer view it presents a more or less pronounced reddish tinge. The rock is traversed by joints, but they are mostly far apart, and it weathers into bold, rounded forms. In places it is deeply decomposed and forms depressions or parks. The surface is usually rough, owing to differential weathering, which often gives considerable prominence to the larger feldspar crystals.

As mentioned above, the red granite grades into the gray variety, and there is generally a very evident transition between them. On the two forks of Big Goose Creek, southeast of Walker Mountain, the change is more abrupt than usual. In places near Little Goose Creek it occurs within a short distance. The transition from red to gray granite is well exhibited on Little Tongue River. The change is marked by gradual increase of the amount of biotite, causing darker color, and the rock becomes harder, finer grained, and more compact in the gray variety. In the northern portion of the red-granite area, north of Black Mountain, some of the granite is soft, but northwest of that mountain and southwest of Rockwood the rock is unusually hard and compact, so that it presents very rugged ledges. About a mile west of the head of Tepee Creek there is a narrow area of pegmatitic rock in the red granite, apparently due to local very coarse crystallization.

In the ridges southwest of Doyle Creek there is an area, about a mile in diameter, of a nearly white granite, or aplite, part of which rises in conspicuous ledges of light color. It apparently merges into the gray granite. Smaller developments of this variety occur at many other points, notably on the ridge east of Tensleep Lake and at the head of Paintrock Creek.

Well-defined gneiss is rare in the Bighorn uplift, although much of the gray granite shows incipient schistosity. A belt of gneiss developes in the granite along a zone about 2 miles wide, extending in a north-south course near the eastern side of the crystalline rock area from north of Clear Creek to Piney Creek, a distance of about 9 miles. The rock is medium to fine grained and dark colored, with distinct banding perceptible throughout. The planes of schistosity are nearly vertical or lean slightly to the west, and the strike is north and south, parallel to the course of the outcrop zone. The rock weathers into large plates or slabs having rounded outlines. On the divide south of Little Goose Peak there are several narrow zones of gneiss in the gray granite, in which in places the laminæ are greatly crumpled, but this is a most unusual feature. Gneissic granite was also observed in the vicinity

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of Dome Lake and at intervals northeastward on the East Fork of Big Goose Creek, at the north end of Walker Prairie, on the main divide west of Dome Lake, along the headwaters of North Fork of Crazy Woman Creek, and in the region south of Hazelton. In a small area southeast of Hazelton a hornblendic gneiss is found.

No special study was made of the distribution of the various rocks in the southern end of the Bighorn uplift nor in the Bridger Range. The rocks present more variety than is found in the northern portion of the uplift, but red and gray granites predominate. Occasional dikes of diabase occur and, near the head of Trout Creek, there is a mass of dark-gray rock which is altered into an impure steatite or soapstone. In the Bridger Range much of the rock is red granite, but there are also extensive masses of black dioritic rocks, some of them highly schistose. The schistosity is a noticeable feature on the road a short distance east of Fogg's ranch.

PETROGRAPHY.

The granitic rocks in the Bighorn uplift present considerable variation in character, but the variations are so irregularly distributed that it is not possible to indicate the limits of the different rocks. The predominating materials, especially in the higher portions of the mountain, are coarse-grained, dark-gray rocks consisting mainly of feldspar, quartz, and mica. The feldspar crystals often are large, giving the rock a porphyritic appearance, but the texture varies considerably. The quartz is usually somewhat less in amount than the other minerals. The mica is mostly biotite, and it is in small proportion.

The feldspars comprise plagioclase, orthoclase, and microcline and the proportions of these vary irregularly in different parts of the region. In some areas there is a preponderance of the plagioclase and the rocks are quartz-diorites, but in the greater part of the region the potash feldspars are in greater proportion. It has not been practicable to distinguish these rocks in the field, and they grade into one another often through intermediate types of quartz-monzonites. Small amounts of apatite, magnetite, and titanite occur as common accessory minerals, while rutile and zircon occur less often. As is usually the case in rocks of this sort, all the minerals are crystalline and in general the grains are nearly uniform in size. The quartz occurs in scattered, irregular patches, often interstitially arranged between the larger feldspars. Hornblende occurs very sparingly and mostly in zones in which a small proportion of the mineral is scattered through the rock. Much of the gray granite shows evidences of a small amount of shearing, but only in a very few areas could the rock be regarded as gneiss. In some areas micrographic intergrowths of quartz and feldspar are common, and secondary minerals of various kinds occur in much of the rock. Portions of the biotite are often altered to chlorite, and some of the feldspar is often altered to kaolin and sericite.

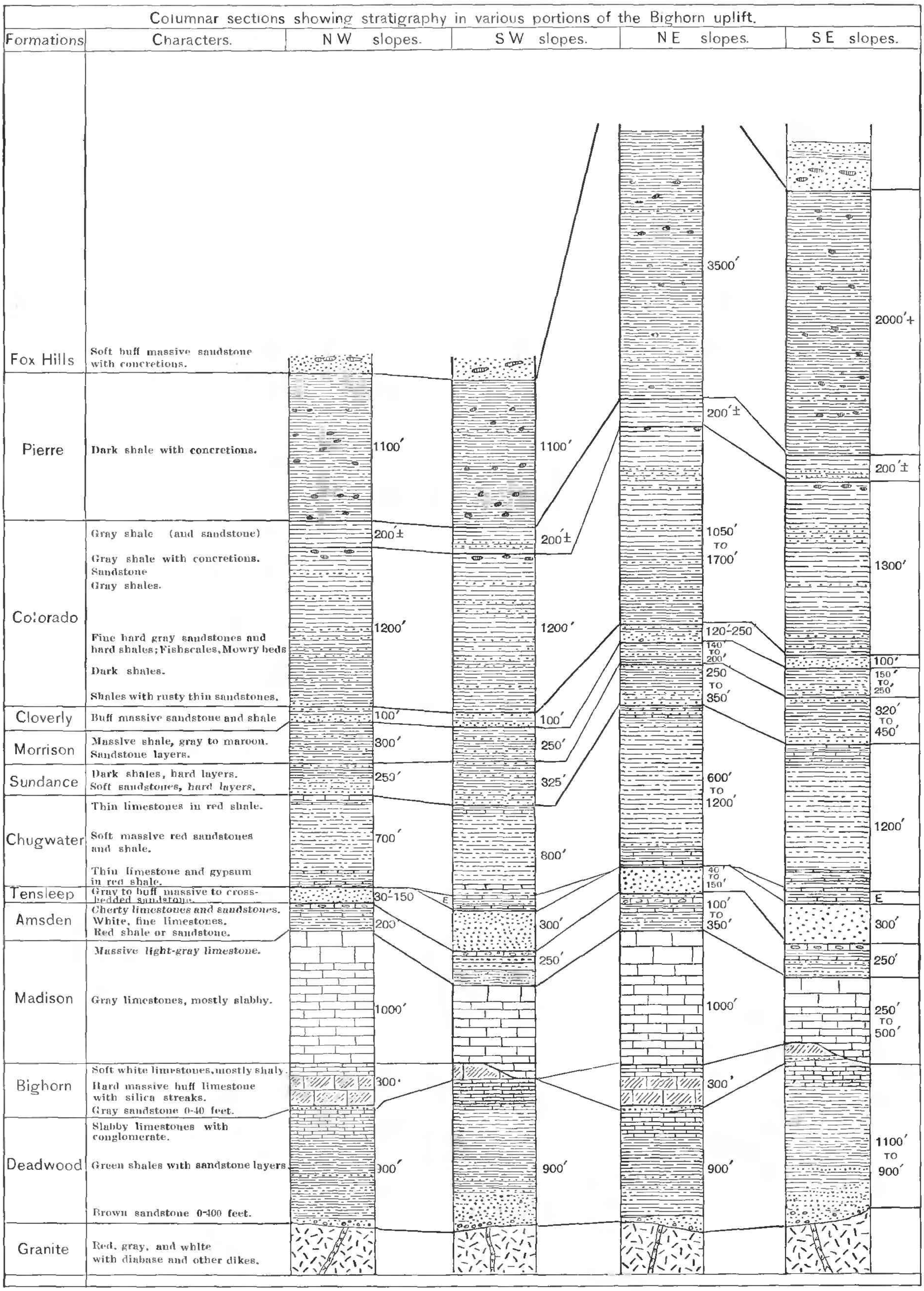
In the red granite the minerals are feldspar, quartz, and mica, with a few minor accessories. The feldspar is mainly orthoclase and microcline with a small proportion of plagioclase, usually oligoclase. The reddish color is due mainly to the dissemination of small particles of iron minerals in the orthoclase. The microcline is sufficiently fresh to present the characteristic cross-hatched structure. Quartz generally occurs in rather prominent crystalline grains, although sometimes it is interstitially arranged between the larger feldspars. The mica is biotite (often

A. LAKE DE SMET NORTH OF BUFFALO, WYO.

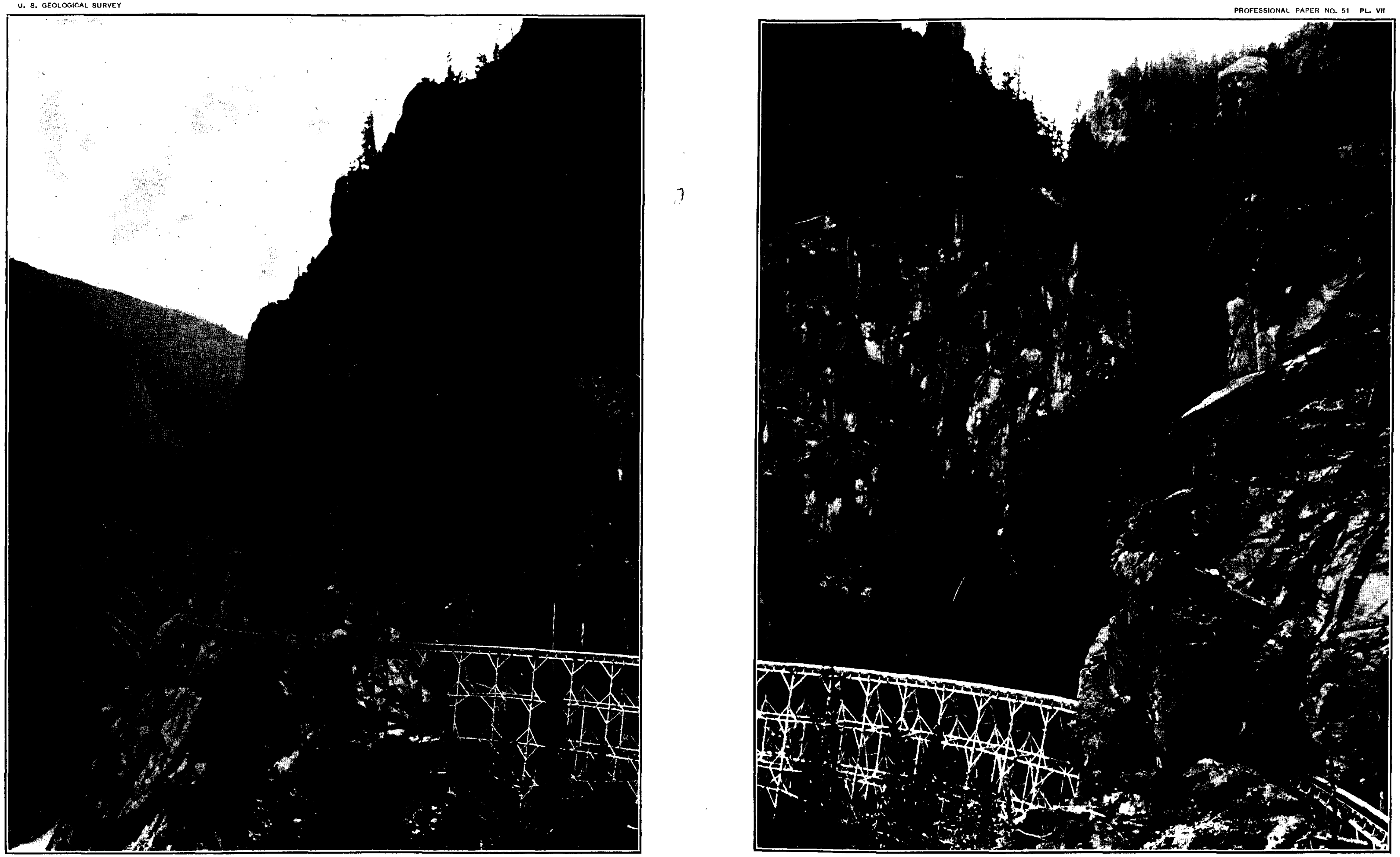
A natural basin in De Smet coal measures. Looking south. Photograph by J. Stimson.

B. MEADE LAKE NEAR HEAD OF SOUTH FORK OF SOUTH PINEY RIVER, BIGHORN MOUNTAINS.

A glacial lake basin in granite; altitude about 9,950 feet. Looking southwest. Photograph by J. Stimson.



COLUMNAR SECTIONS, SHOWING STRATIGRAPHY IN VARIOUS PARTS OF BIGHORN MOUNTAINS.



CANYON OF TONGUE RIVER.

Granite, east side of Bighorn Mountains; showing tie flume. Photograph by J. Stimson.

A. CLOUD PEAK FROM THE SOUTHWEST.

Summit is to right of middle; near right-hand margin is low gap at head of South Fork of South Piney Creek. Glaciated granite topography.

B. CANYON OF NORTH FORK OF POWDER RIVER.

View from Tensleep sandstone of east wall of canyon; looking west. Cliffs to left are Madison limestone, dipping east.

chloritized), and hornblende occurs but sparingly. Magnetite occurs in small particles in moderate amount and the individual crystals have formed without external interference. Minute crystals of apatite are sometimes recognizable. The red granites are generally characterized by a smaller proportion of the darker minerals and an increased amount of microcline.

The white granites, or granite aplites, consist of orthoclase, quartz, microcline, plagioclase, and mica in varying proportions. At the head of Paintrock Creek microcline predominates, and in the area southwest of Doyle Creek orthoclase is the most abundant mineral. At the former locality the mica is muscovite and in the latter it is bleached biotite, in subparallel arrangement. The rocks are medium to fine grained and granular, and the feldspars and quartz are in grains of about the same size.

In thin sections the gneissic granites show small grains of quartz, biotite, and a few minor accessories, surrounding the larger components in a typical gneissoid structure, the whole having a banded appearance when examined with a low power of the microscope. Micrographic intergrowth of quartz and feldspar is common, and secondary minerals frequently occur along the cleavage cracks of the latter. The quartz shows cloudy extinction, and microcline is sometimes interstitially arranged between larger constituents. The contained minerals of the gneiss are the same as those of the granite from which it was derived, with the addition of a few secondary products.

DIABASE.

OCCURRENCE.

The granites of the Bighorn uplift are penetrated by numerous dikes, chiefly of diabase. Most of them trend north of east and south of west, across the axis of the uplift, but some extend in various other directions. They are most numerous in the higher portion of the area, but otherwise they show no special features of distribution. They vary in width from a few inches to 150 feet, but most of them are between 20 and 40 feet wide. The largest one, about 150 feet wide, extends along the high east-west ridge just north of Cloud Peak. The length is very variable, one dike which crosses the central ridge near Middle Fork of Clear Creek having a length of over 14 miles, while many others are more than 5 miles long. The small ones generally range from 2 miles to one-fourth mile in length, and many are very small; probably numerous smaller ones are hidden under talus or fallen timber and were not discovered. Usually the short dikes are the narrowest. The rocks are of black color, and the dikes are generally conspicuous as black streaks in the mountain slopes, and, owing to their hardness, they often stand out in ridges of moderate prominence. In places where the rock is much weathered it breaks into rectangular fragments, generally from 2 to 6 inches in diameter, and the ultimate product of its decomposition is a reddish-brown residual soil which is in striking contrast with that derived from most of the granite.

The largest and perhaps most notable dike of diabase follows the ridge just north of Cloud Peak. It begins north of Lake Solitude and extends east-northeast to the ridge north of Cloud Peak, passing through the peak known as Blacktooth. Its width varies from 50 to 150 feet, and on Blacktooth it sends off a small branch dike

40 feet wide, which forms the summit A smaller dike extends northeast and southwest along the west side of Cloud Peak, crossing the divide about a mile north of the peak. Two large dikes lie a short distance north of this large one and extend to Kearney Lakes, and two others with branches extend east and west along the high slopes south of North Fork of Paintrock Creek Two long, wide dikes extend across the heads of the northerly branches of North Fork, and another extends from near the head of Shell Creek Valley eastward across the divide to Cross Creek In the ridges east and south of Cloud Peak are numerous dikes of various lengths and widths The largest dike in this district begins north of West Tensleep Lake and extends nearly due east across the divide and down the ridge north of Sherd Lake North and east of East Tensleep Lake are several dikes 10 to 50 feet wide, generally trending southeast and northwest In the southern part of the area the dikes are from 10 to 40 feet wide and the directions are variable South of Hazelton dikes occur every mile or two and trend on parallel courses east and northeast. They are from 5 to 25 feet wide, and the width varies somewhat in the same dike Here also veins of quartz occur along some of the diabase-granite contacts.

The longest dike in the southeastern portion of the main crystalline area begins in the divide south of Sour Dough Creek as a continuation of the dike of hornblende diorite, and extends due northeast for 12 miles at least, finally disappearing beneath the Deadwood sandstone near the canyon of Clear Creek Its width is often 100 feet and it gives rise to short ridges and knobs at many points A few rods north is a smaller companion dike which runs parallel for some distance but finally diverges and disappears near the north line of township 49 A large dike outcrops in the ridges west of South Fork of Clear Creek, which finally crosses the large dike extending east from East Tensleep Lake

In the northern portion of the main crystalline rock area, the dikes are most abundant in the ridges about the head of Little Goose Creek and adjoining North and South Piney creeks. Several large ones extend in a rudely parallel course east of Finger Rock and Last Chance Lake, but appear to terminate in slopes west of the trail up Little Goose Creek Others occur along and near the main divide, mostly near the heads of West Fork of Big Goose Creek and at points westward Another extends across portions of township 55, in ranges 87 and 88, and several occur near the mouth of South Fork of Tongue River Doubtless there are many small or short dikes in this region in some of the wide areas of down-timber, which have not been discovered. The dikes between Shell Creek and the head of South Fork of Tongue River are mostly from 5 to 20 feet wide and from a few hundred yards to 3 miles in length The dike which extends across the main road just east of the divide, about 4 miles northeast of Antelope Butte, is a conspicuous one and has a width of about 55 feet It was traced for about 2 miles, and it appears to end in slopes to the south and in the 10,000-foot knob to the north The dike extending northwest from Willitt Creek east of Antelope Butte is similar, and was found to be nearly 3 miles long, possibly appearing again on the main divide northwest, along a continuation of the same course. A long dike extends from near Walker Prairie westward nearly to South Fork of Tongue River, a distance of 6 miles Its width varies from 15 to 25 feet. The dikes near the mouth of South Fork of Tongue River are of variable widths and lengths.

The larger one has a width of about 20 feet. The dike near the mouth of Tepee Creek is about 60 feet wide, and another mass near by, which appears to be a branch, is 35 feet wide.

Diabase dikes cut the granite at various points in the vicinity of Bald Mountain and on Porcupine and South Beaver creeks. A large branching dike appears in the granite of the Dry Fork anticline in the canyon of Little Bighorn River, and another dike crosses this stream near its headwaters, about 2 miles northeast of Duncom Mountain. One of the longest dikes in this region begins northeast of Bald Mountain Cabin and extends southwest for over 5 miles, disappearing under the Deadwood sandstone at either end, and also for some distance under the Bald Mountain ridge. Its width is about 25 feet. A branch extends north-northeast from the main dike, in the granite plateau west of Bald Mountain, passes under the Deadwood sandstone for about a mile east of Medicine Mountain, and appears to continue north in one of the dikes crossing Porcupine Creek, a length in all of at least 5 miles. A number of small dikes, or chimneys, of diabase appear in the vicinity of Fortunatus Mill, especially to the southwest. They are from 10 to 20 feet in diameter and of circular or elliptical outline. These small masses are mineralized somewhat with quartz and iron oxide.

Veins of quartz occur in connection with some of the basalt dikes, either side by side sharing the same fissure, or occupying a continuation of it. The quartz is mostly white, but some is bluish and in places rusty with oxide of iron. Sometimes quartz veins cross the dikes. One vein of white to bluish-white quartz 20 feet wide extends a mile southwest from near the mouth of Tepee Creek. It is partly massive and partly in crystals.

PETROGRAPHY.

The rocks are nearly all very fine grained, dark, and hard. The constituent minerals of the diabase are feldspar, augite, and quartz, with biotite, magnetite, chlorite, and apatite occurring in smaller amounts. The feldspars range from oligoclase to labradorite. They are usually in lath-shaped crystals which generally have clearly defined boundaries and contain a medium to high percentage of lime. Twin lamination on the albite and carlsbad laws are common, and pericline twinning is sometimes seen. The common pyroxenic constituent is augite, which usually occurs without crystal outlines and in thin sections is nearly colorless. It sometimes alters to a fibrous serpentine. Quartz is present in scattered patches of varying dimensions and is often cracked and broken. A light-brown biotite occurs as an accessory, but is usually chloritized. The iron ores include magnetite and perhaps ilmenite, frequently in skeleton forms. Needle-like crystals of apatite are not uncommon.

A diabase of typical character, from a dike on a southern prong of East Tensleep Creek a mile southwest of the 11,676-foot summit, has the following characters: Its texture is ophitic, but differs somewhat from the usual ophitic texture in that it has the feldspar in smaller laths and in bunches, while augite forms about half of the rock. The feldspar is plagioclase, probably labradorite, and about equals the augite in amount. Some magnetite occurs, as in most of the rocks. There is a beautifully exposed contact between quartz-diorite and a fine-grained diabase on the mountain side 2 miles southwest of the head of Kearney Lakes. It is along a curving line, in places somewhat jagged. The diabase is very fine grained at contact, but farther away it is porphyritic with plagioclase phenocrysts. These phenocrysts are lath-shaped and the groundmass is finely ophitic. Near the contact the groundmass is darker and finer grained. There is almost no plagioclase and the hornblende and magnetite increase, there being much more magnetite near the contact than elsewhere.

OLIVINE GABBRO.

A large dike of rock rich in olivine extends across the axis of the Bighorn uplift, crossing the divide about 2 miles northwest of Cloud Peak. It begins southeast of Paintrock Lakes and, trending east, crosses the valley of North Fork of Paintrock Creek at an altitude of 8,700 feet, and passes a short distance north of the 12,503-foot summit on the divide In this vicinity it turns to the east-northeast, and, passing a short distance north of Blacktooth, finally disappears beneath the glacial drift east of Kearney Lakes Its width averages nearly 200 feet in the greater part of its course, and it has a few small branches. Two other small dikes of the same sort of rock were discovered—one a mile east of the upper end of Lake Solitude and another 1½ miles northeast of Black Butte. The rock is black, its structure coarsely granular, and in places it shows narrow black phenocrysts up to one-fourth inch in length. Under the microscope the texture is seen to be hypidiomorphic granular, with the femic minerals exceeding the salic in quantity. The constituent minerals appear to vary somewhat in their proportions, but in most of the rock the chief minerals are augite, plagioclase, olivine, hypersthene, biotite, and hornblende, listed in order of abundance, with magnetite, apatite, and rutile as accessory minerals Another variety, also from the west side of Cloud Peak, is classed as a lherzolite, consisting of orthorhombic pyroxene (enstatite), olivine, monoclinic pyroxene (diopside), and smaller amounts of plagioclase, biotite, and magnetite.

HORNBLENDE-DIORITE.

A wide dike of this rock extends north-northeast up the valley of North Fork of Powder River from a point 4 miles due southwest of Hazelton Peak, and across the head branches of North Fork of Crazy Woman Creek, a distance of about 10 miles. Its width varies from 100 to 200 feet. At its north end it appears to give place to two dikes of diabase. It cuts granite, except for about a half-mile in Powder River Valley, where it either cuts, is cut by, or merges into an amphibolite- or hornblende-schist As the contact relations were not clearly exposed, the relations of the two rocks were not determined. The rock is granular and, as five-eighths of the constituents are dark, it is of dark color. Under the microscope its texture is seen to be hypidiomorphic granular, and its chief constituents are plagioclase, green hornblende, and biotite, with magnetite, titanite, and apatite as accessory minerals and sericite, muscovite, and epidote as secondary minerals.

AMPHIBOLITE-HORNBLENDE-SCHIST.

A narrow belt of this rock extends across the granite area from the headwaters of Middle Fork of Crazy Woman Creek to Canyon Creek, where the latter crosses the 9,000-foot contour line. West of Powder River it is mostly covered by terrace deposits. Its greatest width is 3,000 feet. It appears to blende into the granite at some points, but no clear exposures of contact were found. The rock is similar to aggregations of dark minerals occasionally found in irregular streaks and blotches in the granite, but probably in this area it is a separate dike. Much of the material is schistose, and breaks into plates with glistening surfaces covered with hornblende crystals in parallel arrangement. Under the microscope the texture is seen to be schistose, flattened, hypidiomorphic granular. The principal constituents are green hornblende, generally unstriated, and plagioclase. Quartz is in small amount. Magnetite, apatite, and titanite occur as accessory minerals, the titanite often surrounding the magnetite.

Four miles southeast of East Tensleep Lake there is a mass of amphibolite supposed to be a dike. It is a dark-gray schistose rock, nearly black, with black glistening hornblende crystals mingled with white specks, all very small and fine grained. Under the microscope the texture is seen to be hypidiomorphic and the femic and salic minerals about equal in amount. The chief constituents are plagioclase, some of which is labradorite, green hornblende, and lesser amounts of intersertal quartz and biotite, with magnetite and apatite as accessory minerals. The present schistose structure obliterates the original structure.

PERIDOTITE.

In the ridge west of the lower portion of South Fork of Tongue River there is a long dike of peridotite, which appears to be the only occurrence of rocks of this sort in the area. It is deeply decomposed, but under the microscope appears to consist largely of olivine, diopside, and hornblende, with considerable magnetite. It is probably near the variety of peridotite known as welvelite or lherzolite.

CAMBRIAN SYSTEM.

DEADWOOD FORMATION.

General relations.—This formation consists of sandstones, shales, and limestones, having an average thickness of 900 feet. Its outcrop encircles the central granite areas and extends along portions of the crest of the mountain west of longitude 107° 30′ nearly to the Bighorn Canyon and southward from the head of Beartrap Creek to beyond Okie's store. As compared with the underlying granite and overlying Ordovician limestone, most of the rocks are soft and generally give rise to rounded slopes and low saddles on the mountain spurs. Bald Mountain is a notable example of this feature, rising as a huge rounded mound about 800 feet above the platform of granite. Little Bald and Cone mountains are similar but smaller areas, while in Sheep, Medicine, Duncom, and Hunt mountains there are long slopes of Deadwood beds capped by Bighorn limestone. In the areas adjoining the central granite uplift the outcrop zone usually is narrow, especially where the dips are relatively steep, as in the slopes west of Sheridan and Buffalo. In the Bald Mountain ridge the dips are low and the formation presents a wide surface exposure extending far down the valleys of Little Bighorn and Tongue rivers and Lodge Grass and Shell creeks. For some distance south of Bighorn, at intervals west of Buffalo, and at a few points along the west side of the range the formation is cut out by faults for short distances. Near latitude 44° and a short distance south the formation extends entirely across the southern end of the higher portion of the uplift and passes beneath the Bighorn and Madison limestones It reappears in the deep canyon of Beartrap Creek and on the mountain summit westward. Thence southward the hard basal sandstone member constitutes the summit ridge to the southern end of the mountain. In this area the outcrop attains a width of over 5 miles for a considerable distance and the amount increases to 10 miles along the valley of the West Fork of Powder River. The sandstone caps numerous high ridges on the west slope of the mountains west of the heads of Deep and Badwater creeks and it appears again extensively in the Bridger Range, especially on the east and north slopes and in the deep canyon of the Bighorn River west of Fogg's ranch.

Stratigraphy.—The succession of beds in the Deadwood formation is nearly uniform over the entire area of the Bighorn uplift. At the base there are usually coarse-grained, reddish-brown sandstones from 10 to 200 feet in thickness, which often are sufficiently hard to be marked by a prominent shelf where the dips are moderate. Next above are sandy shales and thin-bedded sandstones, usually about 200 feet thick, which merge into 400 feet or more of soft, greenish-gray shales with occasional thin layers of limestone and sandstone Above these are from 125 to 200 feet of slabby limestones, mostly of gray color, but in part flesh colored to brownish buff, and containing frequent layers and masses of a peculiar conglomerate characteristic of the horizon. This rock consists of flat limestone pebbles often intermingled with thin, twisted and broken layers of limestone in a matrix of fine limestone and shale material Some features of this rock are shown in Pl XI, *A*. Many of the pebbles are so thickly covered with grains of glauconite that they appear to be green, but inside they are gray or pinkish, similar to the associated beds. They clearly are intraformational conglomerates The upper limestones of the formation are absent in the area extending from West Fork of Powder River to beyond Okie's store, where the Madison limestone lies directly on the green shales. The base of the formation lies on a remarkably smooth surface of granite, evidently reduced to a plain by earlier Cambrian erosion. At the base of the formation the lower sandstone is usually conglomeratic, containing quartz pebbles mostly of small size The sandstone varies considerably in thickness and hardness. It is most prominent along the crest of the mountain from northeast of Bigtrails southward and along the east side of the Bridger Range, where it is thick and quartzitic. In the region about Granite Creek and for some distance down Shell Creek this member is absent, the sandy shales lying directly on the granite. About Bald Mountain the basal sandstones are about 20 feet thick, but the amount increases rapidly to the northwest, and west of Sheep Mountain a thickness of 60 feet is attained It thickens southward from Paintrock Creek and is at least 200 feet thick in the vicinity of Lee Creek, but less in Tensleep Canyon and southward. On the east side of the range there are many local variations in the thickness of the sandstone, which is thin on Rock Creek, 400 feet thick on Johnson and French creeks (see Pl. X, *B*), 80 feet on Clear Creek, 380 feet near the head of Kelley Creek southwest of Buffalo, 125 to 150 feet thick on Middle Fork of Crazy Woman Creek, 100 feet on Beaver Creek, and about 250 feet along the mountain summit from the head of Otter Creek southward. On the north side of Sisters Hill the lower portion of the Deadwood formation is cut out by a small local fault. The basal sandstone forms the broad outcrops southward from Muddy Creek, especially on the plateaus on either side of Middle Fork of Crazy Woman Creek. In this vicinity it is a coarse-grained coffee-colored rock, massively bedded and in places very hard. At its base it is usually of dark red-brown color and more or less conglomeratic. The conglomerate is conspicuous in the gold prospects at the head of Kelley Creek north of Sisters Hill. In the region south of this locality the sandstone is usually parted into three hard layers, separated by softer beds. In the region west of Sheridan the basal member is commonly from 10 to 30 feet thick, but in a few localities northward from Wolf Creek the sandstone is absent. On West Fork of Powder River, southwest of Barnum, where the basal quartzitic sandstone is 100 feet thick, it is overlain by 325 feet of alternations of gray and chocolate-colored sandstones, all massive but only moderately hard. The medial shales and the upper limestone present but little variation in character and thickness. The proportion of sandstone intermixed or intercalated in the shales varies somewhat in the different regions, but shale sediments predominate throughout. In nearly all localities the shales contain one or two beds of gray to light-brown sandstone, 15 to 30 feet thick, which gives rise to a low shelf or cliff extending along many of the shale slopes. One of these beds 20 to 30 feet thick is a noticable feature on Bald Mountain, in the Deadwood slopes west of Sheridan, and towards the southern and western end of the range. This sandstone member is shown prominently in Pl. IX. In most cases it is about 200 feet above the basal sandstones. In the southwestern portion of the Bighorn region and in the Bridger Range a limestone member appears in the middle of the shale series. On Bighorn River west of Fogg's it has a thickness of about 50 feet and causes a conspicuous ledge. A few hundred feet below is a bed of rich red-brown sandstone 40 to 50 feet thick, separated from the basal sandstone by 60 feet or more of sandy shale.

Section of Deadwood formation in Wolf Creek Canyon, west of Sheridan, Wyo.

	Feet.
White massive sandstone at base of Bighorn limestone	
Thin-bedded limestone, gray, greenish, and pinkish tints, with flat-pebble limestone conglomerate and glauconite	300
Gray and greenish shale with thin limestones and sandstones	300
Brown to buff massive sandstone; many fossils	50
Thin-bedded brown and gray sandstones	50
Gray sandstones and shales	35
Hard, brown, cross-bedded sandstone	6
Brown sandstone and sandy shale	30
Dirty-buff to brown and reddish, soft, cross-bedded sandstone; much glauconite; many fossils	20
Soft, greenish-gray sandstone	12
Buff sandstone with fossils	8
Dark-gray and greenish shales with thin sandstone beds above	200
Coarse-grained, cross-bedded, buff to brown, massive sandstone	30

Thickness.—The variations in thickness of the Deadwood formation are moderate. West of Sheridan numerous measurements gave from 850 to 1,050 feet. Northwest of Buffalo the amount is 900 feet, increasing gradually to 1,150 feet in the vicinity of Sisters Hill and gradually diminishing to about 1,000 feet to the south. In the central portion of the uplift the amount is 900 feet, and this thickness is general at most points northward, except that it diminishes to about 800 feet near Medicine Mountain and locally increases to about 1,500 feet in the lower portion of Shell Creek Canyon In the southern part of the range the thickness averages near 1,000 feet

Glauconite—The mineral glauconite is of widespread occurrence in the Deadwood formation, especially in the sandstones in the lower portion of the shale series It occurs in small disseminated grains of bottle-green color, and sometimes is in sufficient amount to give the rock a decidedly greenish appearance

Fossils—Fossils occur at various horizons in the Deadwood formation. They are of middle Cambrian age, and *Dicelamus politus* and *Ptychoparia owenii* are the principal forms The former are small oval shells which occur in great abundance in the middle sandstones and in limestone layers in the shales, as well as in the upper limestone series The *Ptychoparia* is a trilobite which often occurs in great abundance in the basal sandstone One locality at which they were observed in large numbers is on the main road from Bighorn to Dome Lake, about 2 miles northwest of the mouth of Tepee Creek

ORDOVICIAN SYSTEM

BIGHORN LIMESTONE.

General relations—Probably the most conspicuous sedimentary formation in the Bighorn Mountains is this hard, massive limestone which outcrops in huge ledges surmounting long slopes of Deadwood rocks To the north its thickness averages about 300 feet, including an upper series of about 100 feet of softer, thinner-bedded limestone and a basal white sandstone which have been included in the formation mainly on account of their Ordovician age In the southern portion of the uplift the formation thins out and is absent (see Pl XIII, *B*), but it reappears in the northern and western portion of the Bridger Range

The principal exposures of the Bighorn limestone are in lines of cliffs which face inward on the higher slopes of the limestone front range of the mountains and cap some of the higher ridges in the Bald Mountain region. It is also a prominent feature in the numerous deep canyons leading out of the mountains, especially along Bighorn, Tongue, and Little Bighorn rivers and Shell, Lodge Grass, Wolf, Goose, Rapid, Paintrock, Tensleep, Canyon, Otter, Beartrap, and Crazy Woman creeks Along either side of the higher part of the uplift the outcrop of the formation usually is narrow, but in the Bald Mountain region, where the strata lie more nearly level, some wider areas are exhibited It caps the main divide from Sheep to Duncom mountains and occurs on either side of the upper portion of Tongue River Valley In the high plateau between Tongue River and Cedar Creek it is largely covered by Madison limestone. In Hunt Mountain the formation presents to the west a high, straight escarpment, which is visible from far out in the Bighorn Basin. The formation is cut off for short distances by the great fault south of Bighorn and other dislocations at various points along the uplift, so that it does not reach the surface.

Character.—The massive limestone which constitutes the greater part of the formation is a dolomite, usually of light-buff color, somewhat darker when weathered, having a coarse mat or network of irregular siliceous masses, mostly from one-half to 1 inch in diameter. On weathering this siliceous material stands out a half-inch or more on the rock surface as a ragged network, the purer rock between having been dissolved. The nature of this weathered surface is shown in Pl. XI, *B*. This feature and the very massive bedding are characteristic. It is owing to the softness of the underlying Deadwood shales and the hard, massive nature of the Bighorn limestone that the latter forms high cliffs with a talus of huge blocks of the limestone on the slopes below. In Pls. IX to XIII are shown some prominent outcrops of this member. In the canyons there are close, high walls where the streams cross the formation, and a vertical cliff as the rock rises in the slopes. The upper portion of the formation consists of limestone softer and purer than those below; the bedding is thinner, color white to gray, and parts of the rock are very compact or fine grained, often resembling lithographic stone. There is considerable variation in the local features of this member, and its thickness varies from 75 to over 100 feet. In its basal beds corals occur, often in great abundance, especially along the southwestern side of the uplift. In the greater part of the northern portion of the Bighorn area there is included, a short distance above the coralline beds, a layer of hard, massive limestone with network of silica, similar to the great lower member of the formation, but less marked in character and only from 15 to 25 feet thick. Some shale and sandy limestone beds are also included in most places. On the south branch of Rock Creek the upper member of the formation is an impure, thin-bedded, gray limestone which weathers to a reddish clay and contains large numbers of fossils of the Richmond fauna. Throughout its course there is difficulty in separating the top of this formation from the overlying Carboniferous limestone.

The basal sandstone of the formation is a distinct member separating the massive Bighorn limestone from the limestones and shales of the Deadwood formation. It is most extensively developed in the northern-central portion of the uplift, where its thickness usually is from 25 to 30 feet. The rock is a moderately coarse-grained massive sandstone, mostly of light-gray color. It thins to the northwest and is absent at some localities in the vicinity of Shell Creek and Little Bighorn River. It also thins south of latitude 44°, and finally ends with the termination of the Bighorn limestone a short distance north of Cheever's ranch, excepting in a small area on the West Fork of Powder River 12 miles northeast of Ballard & Fish's store, where it has a thickness of 4 feet.

Thickness.—North of Powder River the Bighorn limestone rarely varies materially from 300 feet in thickness, but in some localities the amount is slightly greater, notably in the lower part of Shell Creek Canyon, where there are two beds of massive siliceous limestone in the upper series. In Beartrap Canyon and the ridges southwest the formation rapidly decreases in thickness until it thins out a short distance north of Cheever's ranch, where the Madison limestone lies directly on the eroded surface of the Deadwood formation (see Pl. XIII, *B*). In an outlying knob 2 miles northwest of Cheever's, the limestone is 25 feet thick and separated from the Deadwood beds by a few feet of white quartzitic sandstone, the basal member of the formation. The characteristic massive limestone with siliceous network reappears in the Bridger Range west of Deranch, at first thin, but gradually thickening to 40 feet on branches of Buffalo Creek southeast of Thermopolis, and to 50 feet or more in the upper canyon of Bighorn River.

Fossils.—The greater part of the Bighorn limestone yields but few fossils. Fragments of maclurinas and corals appear occasionally in the lower massive beds, and as above stated, the coralline limestone near the base of the upper series shows corals in most localities. The principal species is *Halysites gracilis*, a variety of chain coral, which often occurs in large numbers. The locality at which fossils were observed to be most abundant in the lower limestone member is on the top of Medicine Mountain in beds about 100 feet above the base of the formation. The following forms from this place were determined by Mr. E. O. Ulrich. *Streptelasma* sp. undet., *Protarea* n. sp. (massive), *Plectorthis plicatella?*, *Dinorthis pectinella?*, *D. subquadrata?*, *Rhynchotrema capax?* var., *Oxydiscus* sp. undet., *Liospira* sp. undet., *Trochonema* sp. undet. (near *T. robbinsi*), *Holopea excelsa?*, and *Huronia* sp. undet., a lower Galena-Trenton fauna, as nearly as can be ascertained. From the upper beds of the formation, at a point about 3 miles east of Bald Mountain cabins, the following fossils were collected: *Streptelasma* n. sp. (with trilobate calyx), *Calapœcia canadensis*, *Favosites asper*, *Stromatocerium?* n. sp., *Dalmanella testudinaria* var., *Leptæna unicostata*, and *Rhynchotrema capax*. These were determined by Mr. E. O. Ulrich, who regards them of Richmond age. Near the divide at the head of Cedar Creek the upper member of the formation is about 160 feet thick and in its upper beds the following forms were found: *Leptæna unicostata*, *Strophomena fluctuosa*, *Dinorthis subquadrata* (coarsely striated form), *Rhynchotrema capax;* while in the middle beds are *Halysites gracilis* (abundant), *Streptelasma* sp. undet., *Diplotrypa westoni*, *Dalmanella testudinaria* var. (*D. meeki*, W. & S.), and *Zygospira* n. sp. (without radial plications). In the lower beds of the upper member, which lie on the thick massive buff lower member of the formation, were the following fossils: *Streptelasma* n. sp. (with trilobate calyx), *Dalmanella testudinaria* var., *Rhynchotrema increbescens?*, *Trochonema umbilicata?*, *Trochonema* sp. undet., and *Cyrtoceras* sp. undet. (near *C. lysander*). All these forms are of Richmond age.

In the uppermost beds on South Fork of Rock Creek large numbers of fossils are weathered out of the reddish clay, due to the weathering of the uppermost limestone of the series. The fossils obtained at this locality, as determined by Mr. E. O. Ulrich, are as follows:

Streptelasma rusticum Billings.
Streptelasma cf. robustum Whiteaves.
Streptelasma n. sp. (with trilobate calyx).
Lindstromia n. sp.
Favosites asper D'Orbigny.
Proboscina (near frondosa Nicholson).
Monotrypella quadrata Rominger.
Batostoma manitobense Ulrich.
Bythopora striata Ulrich.
Leioclemella sp. undet.
Rhinidictya sp. nov.
?Gonitrypa lateralis Ulrich.
Sceptropora facula Ulrich.
Plectambonites n. var. or sp. (near sericea).
Leptæna nitens Billings.
Strophomena n. sp. (between S. neglecta and S. planodorsata).
Dalmanella meeki Winchell and Schuchert (?Miller).
Dalmanella tersa Sardeson.
Dinorthis n. sp. (distinguished from D. subquadrata by its coarse ribs).
Plectorthis whitfieldi Winchell (small variety).
Rhynchotrema perlamellosa Whitfield.
Rhynchotrema n. var. of increbescens Hall.
Lophospira (cast) sp. undet.
Cyloria depressa? Ulrich.
Eurychilina manitobensis Ulrich.
Primitia lativia Ulrich.
Schmidtella sp. undet.

A good section of the Bighorn limestone is exposed in Wolf Creek Canyon. At the base are about 200 feet of massive, cream-colored, siliceous limestone, typical of the lower portion of the formation. This is overlain by purer, softer limestones in part very fine grained. In these upper members were found *Rhinidictya*, *Dicranopora* near *fragilis*, *Ptilotrypa obliquata*, *Pachydicta* sp. undet., *Primitia* sp. undet., and numerous corals of approximate Richmond age. On Big Goose Creek similar rocks are found; 160 feet of massive limestone lies at the base, with a few maclurinas and coral fragments, then follows a series comprising 10 feet of fine-grained, cream-colored limestone, 42 feet of massive, hard, light cream-colored limestone, in part sandy and with small calcite geodes, 4 feet of coarse-grained limestone filled with corals, including *Halysites gracilis* (small-meshed form) and *Columnaria thomii* Hall (like *C. alveolata* Goldfuss, but with separate corallites), 6 feet of sandy and pure limestone layers alternating, 40 feet of limestone, mostly soft, slabby, and fine grained, and 135 feet of massive cream-colored limestones, cherty in lower part, which may belong in whole or in part to the Madison limestone. These beds contain a few indeterminate coral fragments.

From extensive exposures of the Bighorn limestone near the head of Lee Creek Mr. Ulrich obtained the following species:

Halysites gracilis, *Columnaria alveolata*, *C. halli* var., and *Calapœcia canadensis*, an association regarded as Richmond. At a horizon 5 feet lower the following species were collected: *Streptelasma rusticum*, *Leptæna* cf. *nitens*, *Rhynchonella ? argenturbica ?*, *Liospira* cf. *micula*, *Lophospira acuminata*, *Helicotoma* cf. *marginata*, and a small *Straparollus*-like shell, a Richmond faunule. About 50 feet lower in the same vicinity there was found in the massive member a *Platystrophia* of new species, but believed to be the same as one found in the Trenton limestone of Tennessee. During the summer of 1905 fish remains were found in the basal sandstone of the Bighorn formation at a number of localities on the summit of the mountains midway between Mayoworth and Bigtrails post-offices. The remains were plates, among which Mr. C. D. Walcott has identified *Eriptychius americanus* Walc. and *Astraspis desiderata* Walc., the first mentioned occurring in greater number. These forms are the same as those described by Mr. Walcott from the Harding sandstone near Canyon City, Colo.[a] The sandstone varies from 3 to 10 feet in thickness in this district, and the fossils are scattered more or less numerously through several layers, especially in the beds lying a short distance below the massive limestone.

From the paleontological evidence it is believed that in the Bighorn uplift there is between the two upper members of the Bighorn limestone a general hiatus representing later Trenton, Utica, Eden, and Lorraine time, and in some localities, perhaps, the earlier part of Richmond time.

CARBONIFEROUS SYSTEM.

MADISON LIMESTONE.

Relations and character.—The greater part of the thick limestone series flanking the Bighorn Mountains and capping the lower plateaus on their summit appears to be the same as the Madison limestone of south-central Montana. It averages

[a] Bull. Geol. Soc. America, vol. 3, 1892, pp. 153-167.

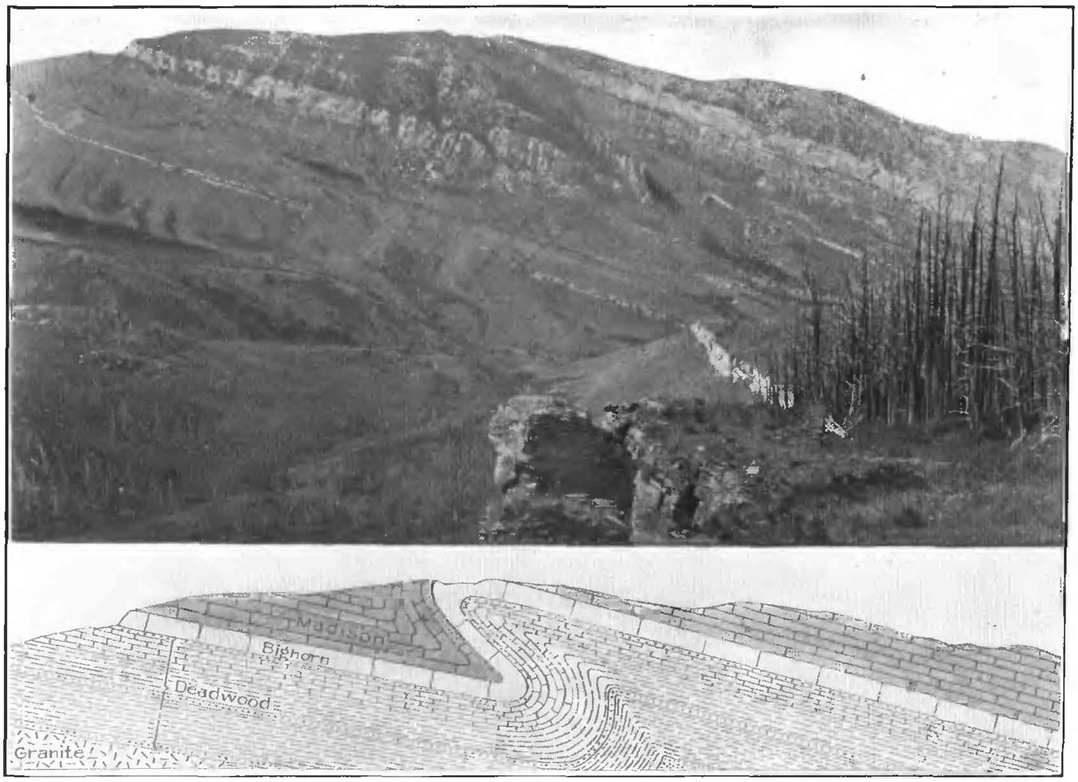
about 1,000 feet in thickness at the north and about half as much to the south and southwest, and consists mostly of light-colored, moderately massive limestone. It constitutes the greater part of the steep outer slopes of the higher portion of the mountains, but west of longitude 107° 30′ extends across their top It pitches beneath the surface at the southern end of the uplift near Deranch, but appears again in the Bridger Range in a prominent flanking ridge. The numerous streams flowing out of the mountains traverse the Madison limestone in canyons often of great depth, having in their walls not only the Madison, but the underlying Bighorn limestone, and in some cases portions of the Deadwood formation The canyons in which the most extensive exposures are exhibited are those of Little Bighorn, Bighorn, Tongue, and Powder rivers, and Lodge Grass, Shell, Paintrock, Medicinelodge, Tensleep, Big Goose, Little Goose, Soldier, No Wood, Buffalo, Deep, Rapid, and other creeks. Other areas of considerable extent are on the slopes of the wide divides on either side of the canyon of the Little Bighorn and south of Shell Creek.

The Madison limestone consists of a lower member of moderately massively bedded hard limestones in part of dark-gray tint, and an upper member about 250 feet thick, of softer, purer, more massive, and lighter-colored rock, which usually weathers in pinnacled forms and caverns. (See Pls. VIII, *B*, XIII, XIV, XV, *A*, and XXXIX, *B*)

Thickness.—The thickness of the formation averages about 1,000 feet in the northern and eastern portion of the uplift, but diminishes to 900 feet in places along the west side, to 800 feet in the region south of Cloud Peak, and to 700 feet and less in areas along the east side of the range south of Crazy Woman Creek. In the southern portion of the uplift and in the Bridger Range the average thickness is about 500 feet In the vicinity of West Fork of Powder River the amount is considerably less, and in one section 10 miles west of Barnum the thickness is only 250 feet; at the top are 70 feet of the usual typical massive member, and at the base for a few feet the limestone is buff and cherty and lies directly on the top limestones of the Deadwood formation West of Houck's the thickness is 400 feet.

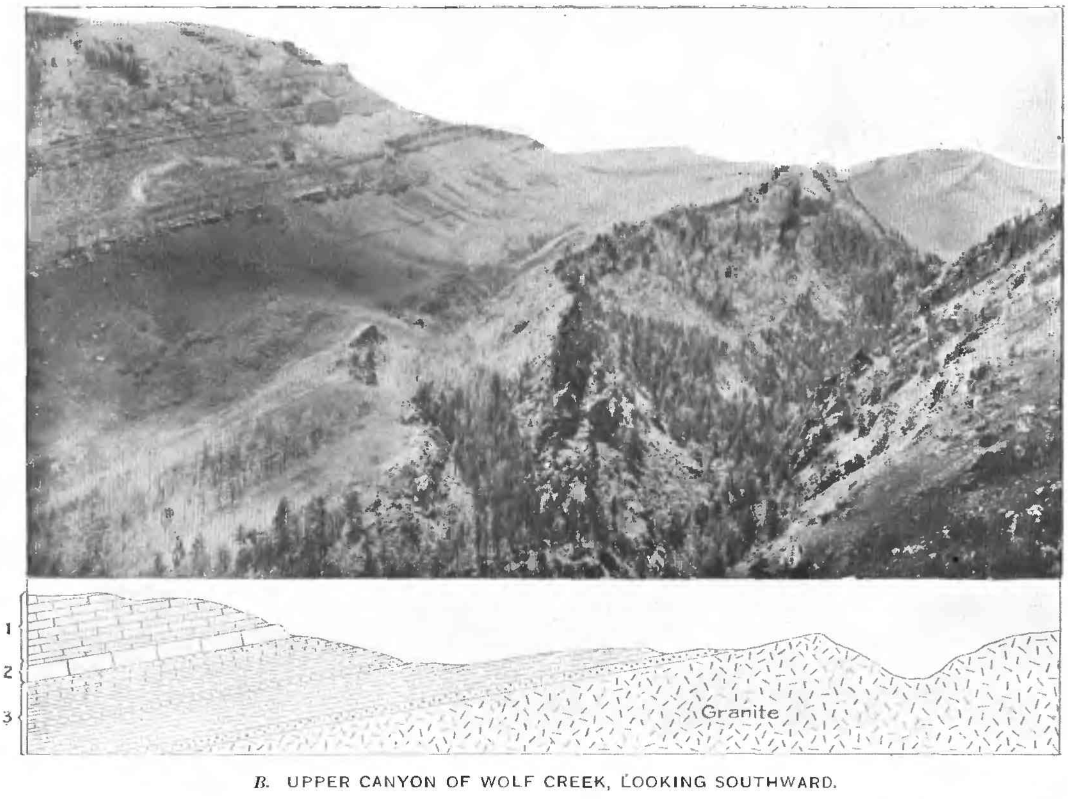
Fossils.—Fossils occur abundantly at various horizons in the Madison limestone, especially in its middle and upper portions. *Spirifer centronatus*, *Seminula humilis*, and *Chonetes loganensis* are the principal forms, and these indicate that the formation is of Mississippian age, the same as the Madison limestone of Montana and the Pahasapa limestone of the Black Hills

In the lower part of Little Bighorn Canyon there were collected, besides the forms above mentioned, *Rhipidomella michelini*, *Eumetria verneuiliana*, and *Camarotœchia* sp. On the north side of Shell Creek Canyon, besides all of the above forms, there were found *Schuchertella inæqualis*, *Syringothyris carteri*, and *Camarotœchia herrickana* On Muddy Creek, a few feet above the Bighorn limestone, the following forms were obtained *Syringopora surcularia*, *Schuchertella inæqualis*, *Camarotœchia sappho ?*, *Fistulipora* sp , *Fenestella* sp., and *Seminula ?* sp. A short distance north these beds yielded the two forms first mentioned, together with *Spirifer centronatus* and *Rhipidomella ?* sp. In the medial beds at the head of north Fork of Shell Creek the following species were collected. *Schuchertella inæqualis*, *Chonetes loganensis*, *Spirifer centronatus*, *Spiriferina solidirostris*, *Seminula humilis*, *S. madisonensis*, var. *pusilla*, *Eumetria verneuiliana*, and *Camarotœchia metallica* All these were determined by Dr. G. H. Girty.



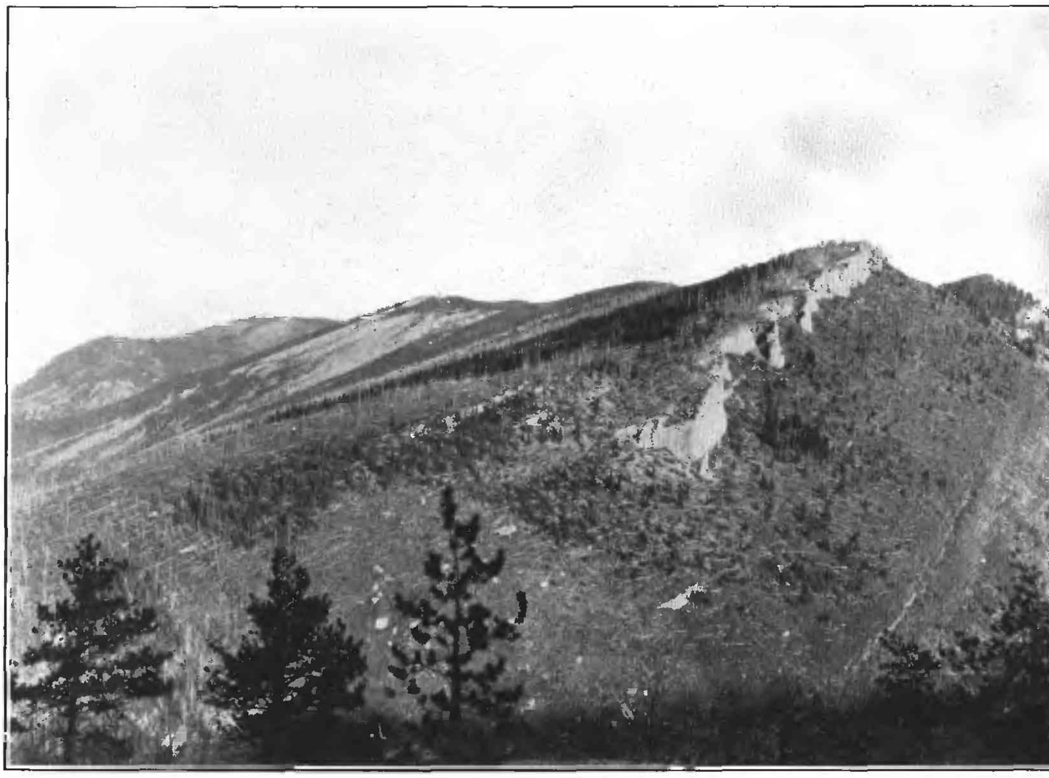
A. VIEW NORTHWARD ACROSS WOLF CREEK CANYON TO LIMESTONE FRONT RIDGE ON EAST SLOPE OF BIGHORN MOUNTAINS.

Deadwood medial sandstone bed in foreground and extending along slopes to left; high cliffs of Bighorn limestone in distance, sharply flexed upward to top of ridge in middle; Madison limestone slopes above.



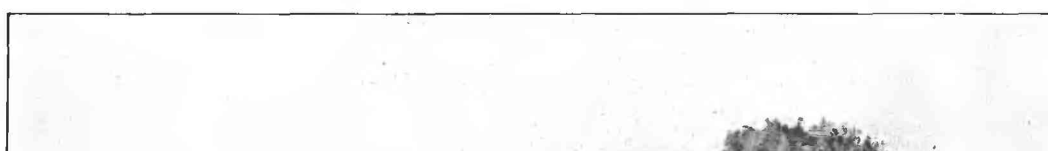
B. UPPER CANYON OF WOLF CREEK, LOOKING SOUTHWARD.

Granite to right, Deadwood slopes to left surmounted by cliffs of Bighorn and Madison limestones; Walker Mountain in distance to right. 1, Madison limestone; 2, Bighorn limestone; 3, Deadwood formation.



A. EAST SLOPE OF LIMESTONE FRONT RIDGE OF BIGHORN MOUNTAINS.

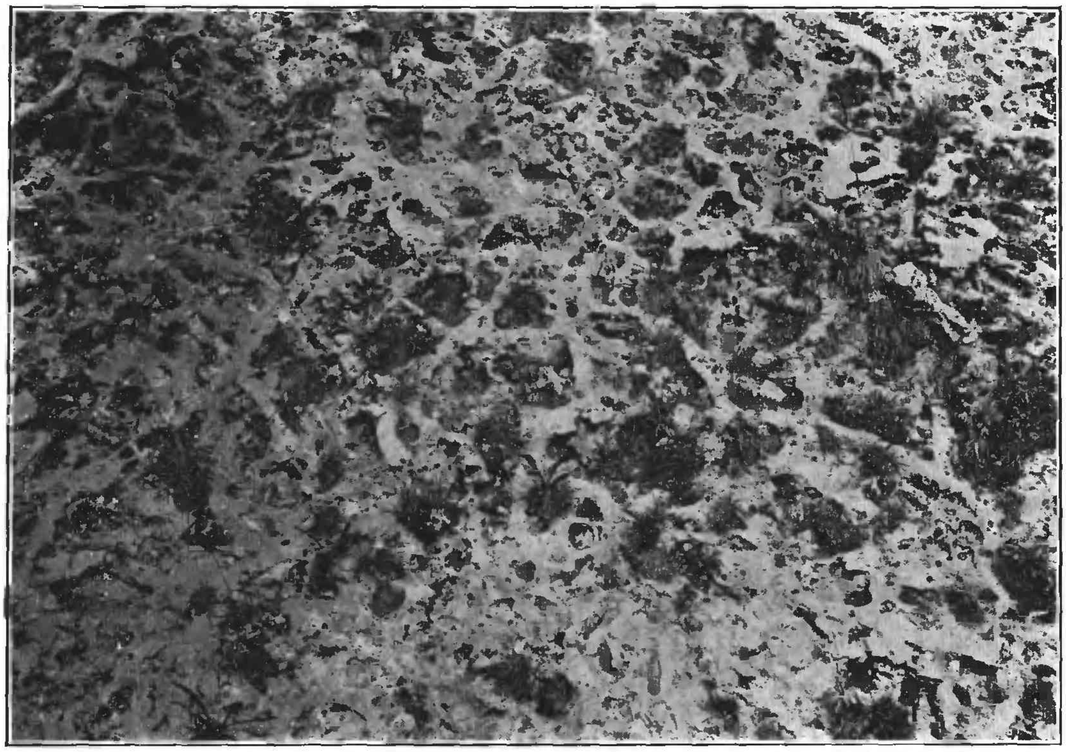
Summits to right are Bighorn limestone surmounting slopes of Deadwood formation and overlain to left and in distance by Madison limestone. Looking south from north side of canyon of Little Tongue River.



B. GRANITE, DEADWOOD FORMATION, AND BIGHORN LIMESTONE ON JOHNSON CREEK, EAST SLOPE OF BIGHORN MOUNTAINS.

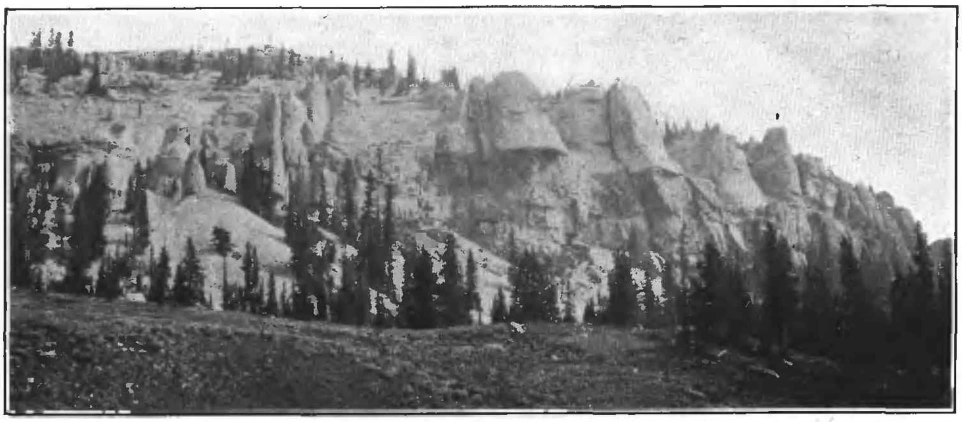
Northwest of Buffalo, Wyo.; looking west. Granite on left side of creek, overlain by thick basal Deadwood sandstone on right side. Deadwood shales and limestone above capped by Bighorn limestone in characteristic cliffs; Piney beds brought down by a great fault at extreme right.

A. TYPICAL FLAT-PEBBLE LIMESTONE CONGLOMERATE OF DEADWOOD FORMATION.



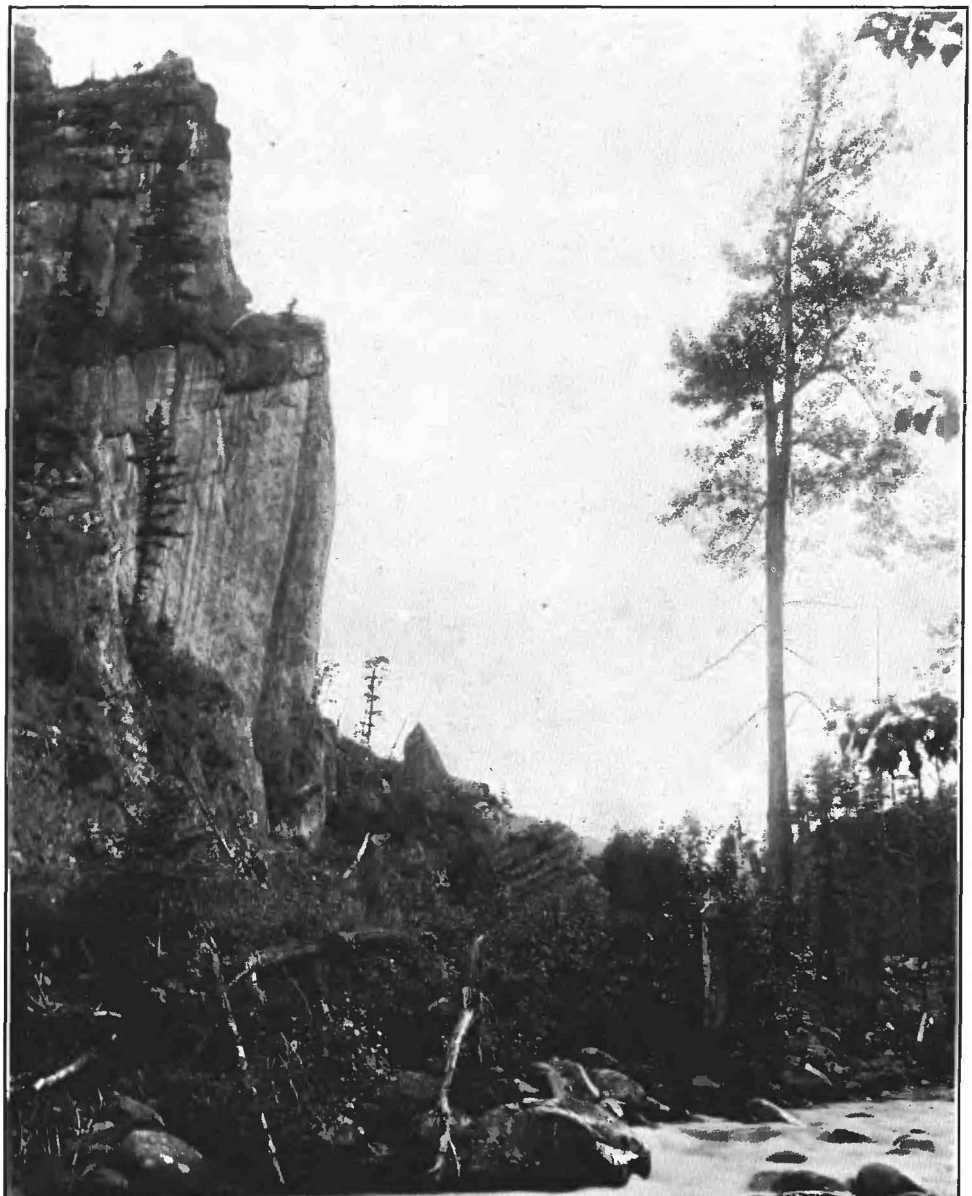
B. TYPICAL WEATHERED SURFACE OF BIGHORN LIMESTONE.

Shows projecting reticulations due to silica. The space represented is about 4 by 5 feet. Photograph by C. D. Walcott. 4160



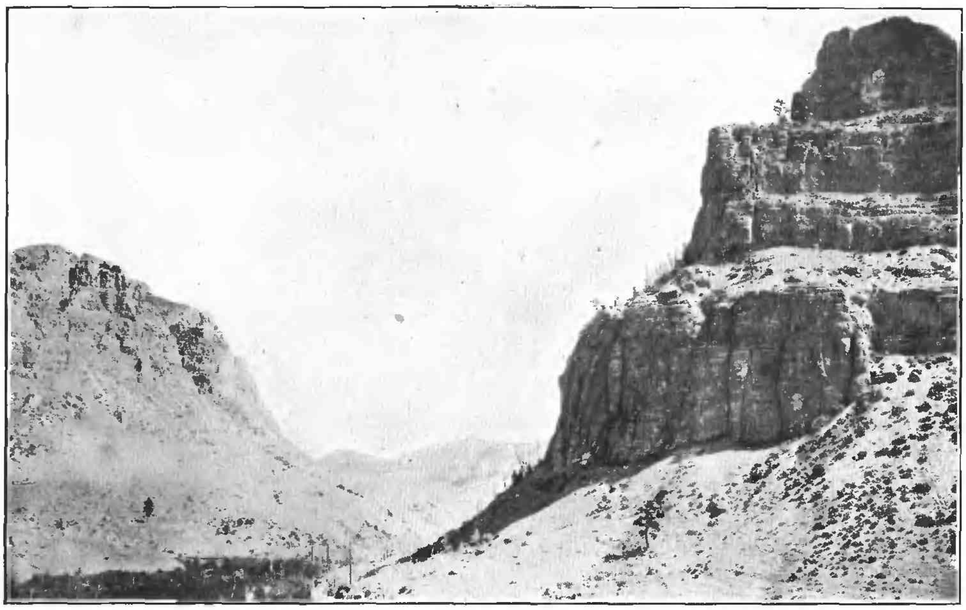
A. TYPICAL CLIFFS OF BIGHORN LIMESTONE.

Southeast of Bald Mountain. Photograph by C. D. Walcott.



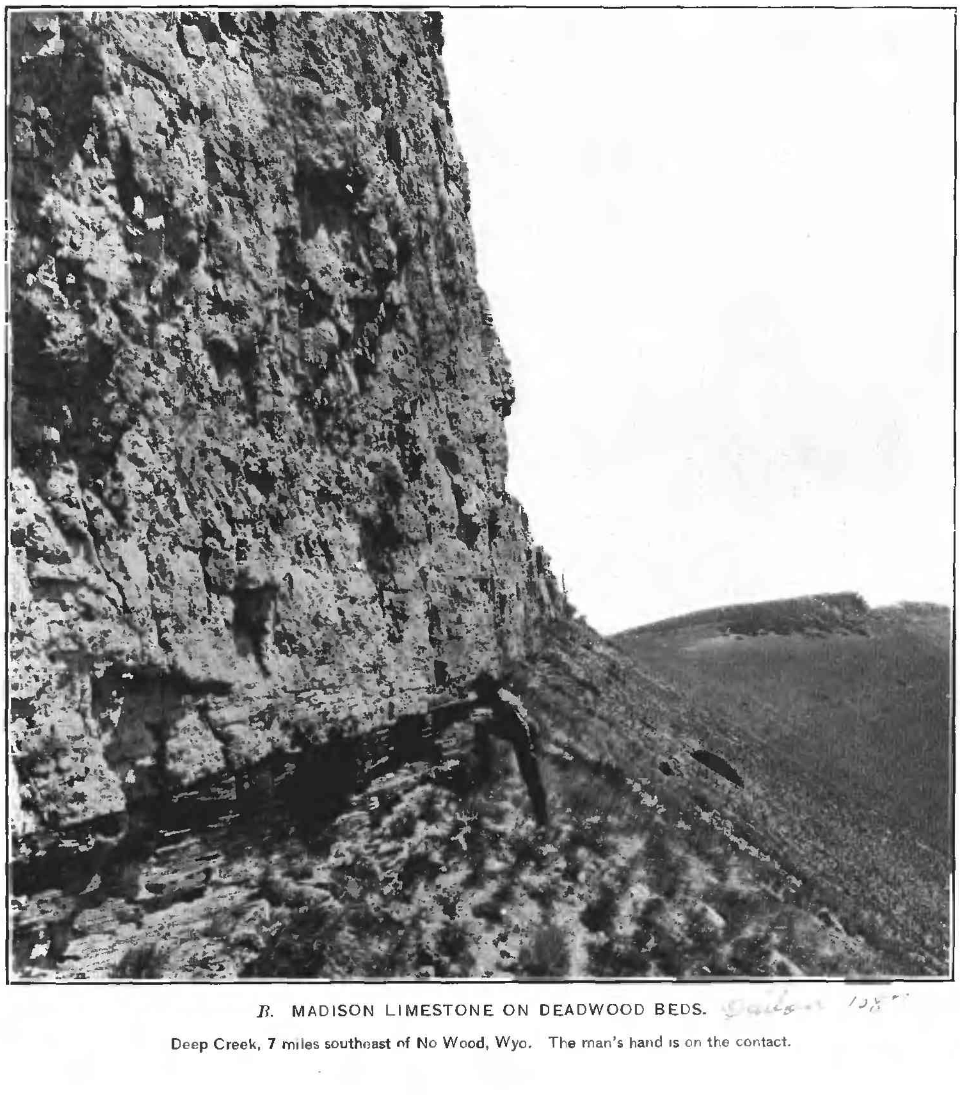
B. TYPICAL CLIFF OF MASSIVE MEMBER OF BIGHORN LIMESTONE.

Piney Creek; east side of Bighorn Mountains, looking west. Photograph by J. Stimson.



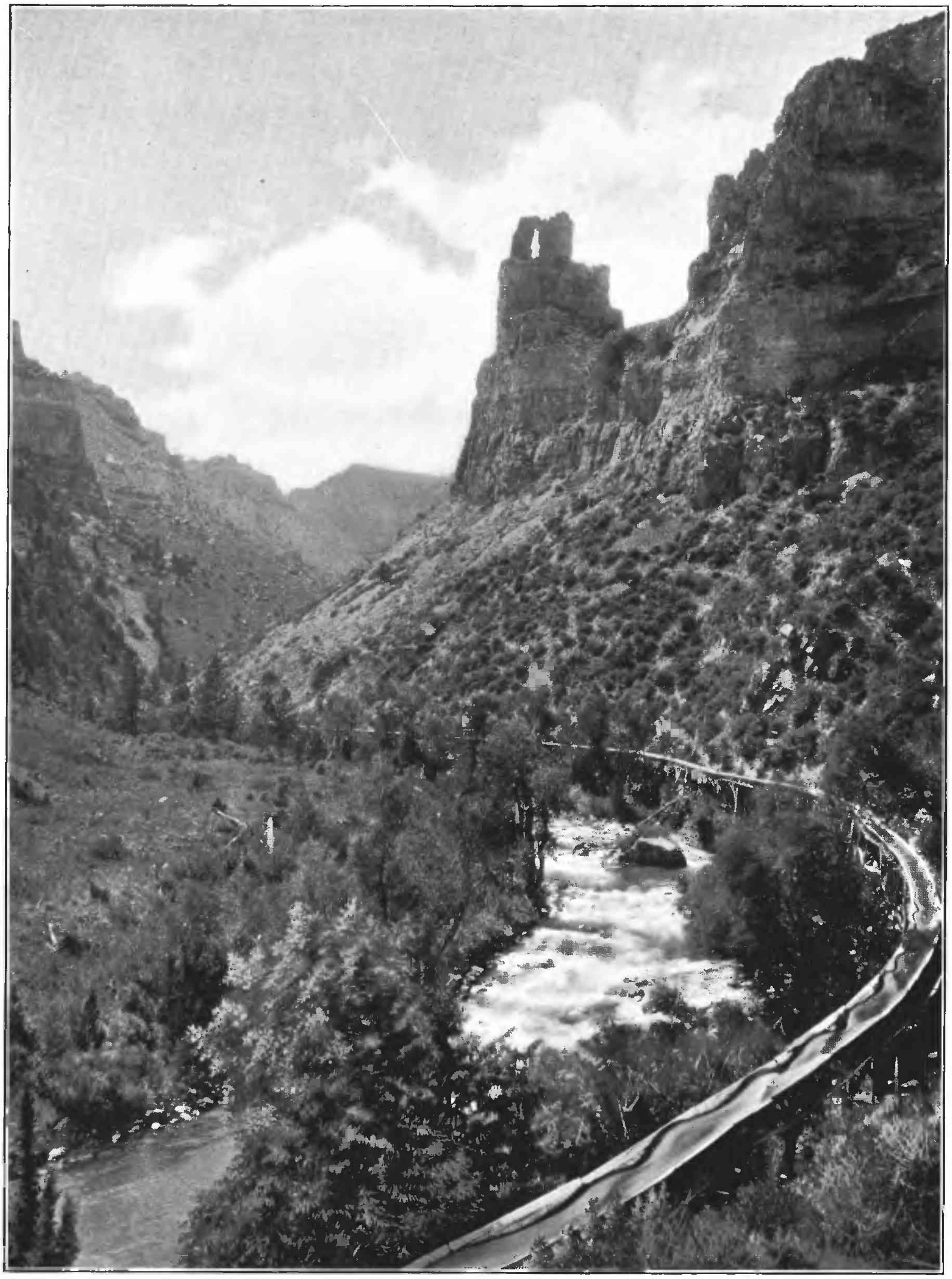
A. TENSLEEP CANYON.

Walls of Bighorn and Madison limestones, the former conspicuous in lower cliff to right. Looking northeast. Darton 85



B. MADISON LIMESTONE ON DEADWOOD BEDS. Darton 125

Deep Creek, 7 miles southeast of No Wood, Wyo. The man's hand is on the contact.



TONGUE RIVER CANYON.

East side of Bighorn Mountains. Shows walls of Madison limestone with characteristic castellated erosion forms of its upper member. Looking west.

AMSDEN FORMATION.

General relations and character.—Overlying the Madison limestone there is a series of red shales, limestones, sandstones, and cherty beds, which has been designated the Amsden formation. Its average thickness is between 200 and 250 feet. Its outcrop extends continuously along the middle slopes on both sides of the mountains, except at a few localities, where for short distances it is cut out by faults or overlapped by younger formations, as in a portion of the region west and northwest of Buffalo and north of Badwater Creek. Along the east side of the mountains, especially west and south of Sheridan, and on the west side from Willow Creek to Shell Canyon the dips are steep and the outcrop zone is narrow, but in the regions between White and Canyon creeks, from North Fork of Powder River to south of Houck's, south of No Wood, east of Thermopolis, and along the northeast slope of the mountain in Montana the dips are low, and wide areas of Amsden beds are exposed. Outlying areas of the formation occur on the sloping plateaus north and south of Shell Creek and between the head of Tongue River and Lodge Grass Creek, and a small area lies in the syncline along Dry Creek. Another outlying area appears south of North Fork of Powder River near the southern margin of the area, where it is brought into contact with the Bighorn limestone and Deadwood formation by a fault. Otter Creek and its branches cut deeply into the formation in the slopes northeast of Bigtrails. Throughout the Bighorn Mountains there is at or near the base of the formation a deposit of red shale, which lies directly on the upper limestone of the Madison formation, except locally to the south, where it is separated by a bed of brown or gray sandstone. Above the red shale there is a variable succession of pure, white, fine-grained, compact limestones, gray to brownish sandstones, red shales, and cherty limestones. At the top there usually are slabby sandstones, especially to the southwest, where they take the place of the greater part of the limestone beds.

The local basal sandstone above referred to attains its maximum development in the canyons of Otter Creek, where it has a thickness of 80 feet. In the vicinity of Tensleep Canyon its thickness is over 40 feet. It is coarse grained, of gray color, and cross-bedded. Some features of this member are shown in Pl. XVI, *B*. It was observed to extend as far north as Paintrock Creek and southward to beyond Little Canyon Creek. The red shale member varies from 25 to 100 feet in thickness and is often parted by 10 feet or less of hard fine-grained, white or flesh-colored limestone resembling lithographic stone. In the vicinity of North Fork of Crazy Woman Creek the red shale is very sandy and gives place, in part, to a massive, moderately fine-grained sandstone, mostly red, but with some ledges of buff color, having a thickness of about 60 feet.

The middle and upper portions of the formation consist of limestones and sandy beds, as above mentioned, and except in the vicinity of Tensleep Canyon there are, near the top, large deposits of chert, which usually weather out and accumulate on the surface of the Amsden. Heavy beds of chert are a conspicuous feature along portions of the east slope west of Sheridan and south of Buffalo. On the mountain slopes the basal red shales usually cause a small saddle out of which rises a knob or bench of the harder overlying beds.

Local features.—A long exposure of the Amsden formation in the canyon of North Fork of Crazy Woman Creek reveals about 60 feet of fine-grained sandstones, mostly red, but with some ledges of buff color; 80 feet of a succession of fine, white, very compact limestones, with red and buff shale intercalations; a few feet of impure, light-colored limestones filled with gray and bluish chert; 40 feet of white limestones with partings of purplish shale; 30 feet of impure limestones with much gray and brown chert, and at the top 25 feet or more of alternations of impure limestone and sandstone—225 feet in all. One and one-half miles south of Johnson Creek 320 feet of the Amsden formation were measured, including a thick mass of basal red beds and a succession of fine, white, compact limestones, with less chert and sand admixture than in the region farther south. West of Sheridan the formation shows a gradual increase in thickness from 150 feet near the Montana line to 350 feet near Little Goose Creek. The basal red sandy shale or fine-grained red sandstone is from 50 to 100 feet thick, the amount gradually increasing to the south. On Rapid Creek the thickness of the formation is 280 feet, comprising about 90 feet of basal red deposits. On Goose Creek the lower series, 165 feet thick, consists of red beds with shales of a lighter color, and the upper series contains typical compact white limestones interbedded with sandstones, shales, and cherty limestones. On Wolf Creek the formation is 350 feet thick, with 100 feet of red shales and fine-grained red sandstones at the base. In the canyon of Little Tongue River there it a very clear exposure of the formation 190 feet thick, showing the following succession:

Section of Amsden formation, on Little Tongue River, Wyoming.

	Feet.
Tensleep sandstone	
Pinkish and greenish shales	20
Light-buff sandstone	6
Pink and green sandy shale	30
Light-gray sandstone	6
Light-maroon shale	10
Hard, cherty, sandy, lime rock (weathers dark)	15
Red, pink, and maroon shale	25
Light-gray calcareous sandstones	12
Red shale	40
Pure, white, very compact limestone	6
Red shale	20

About the head of the branches of Amsden Creek there occurs, in the middle of the formation, a thin bed of dark-gray sandstone with a few conglomeratic streaks, and 20 feet of red shale. Near the Montana line a section is presented which comprises the usual basal bed of red shales, 50 feet thick, sandy, and light colored at the top; 25 feet of very compact, pure white limestones, and an upper series consisting of 50 feet of purplish and buff shales with intercalated beds of sandstone and compact white limestone, in part cherty, and a 7-foot bed of gypsum near the top. The latter is a most unusual feature. In the Montana portion of the area the formation is about 100 feet thick on the east side of the mountains and 160 feet on the west side. Near Bighorn River red shales alternate with the white limestones and cherty limestones nearly to the top of the formation (see Pl. XV, *A*). In the vicinity of Shell Creek, and for some distance northward, the formation averages 170 to 200 feet in thickness, the larger amount being about Devil Canyon and at the mouth of Horse Creek Canyon. Near the base of the formation in this region there occur very peculiar concretions made up of mammillary masses of silica in thin sheets, which in appearance suggest a coral, but are not of organic nature. They vary in size generally from 6 inches to 2 feet.

Section of Amsden formation on Shell Creek, east of Shell, Wyo.

	Feet.
Pink sandstone overlain by flesh-colored massive sandstone of Tensleep formation	4
Light red to maroon sandy shale	40
Gray sandy limestone, thin-bedded at top and containing much chert	20
Red shale	75
Hard, fine-grained, flesh-colored limestone	10
Red shale lying on blue-gray Madison limestone	25

In the vicinity of Paintrock Creek and the slopes west of Black Butte basal gray sandstone appears with a thickness of about 10 feet. It is succeeded by about 50 feet of red shales capped by about 10 feet of hard, fine-grained limestone containing much chert. The upper portion of the formation consists of slabby sandstone, shales, and white limestone, about 125 feet in thickness, the upper beds here and southward being so sandy that it is difficult to draw the line between the Amsden and overlying Tensleep sandstones. The basal sandstone thickens gradually to the south, having a thickness of 40 feet in Tensleep Canyon and 30 feet on Canyon Creek and southward. On Tensleep Creek the red shales are from 30 to 50 feet thick, succeeded by a small amount of limestone, which is capped by 100 feet or more of slabby sandstone with occasional thin beds of cherty limestone in its lower portion.

On Red Fork of Powder River the formation consists mostly of sandstone with 80 feet of sandy red shales at base. West of Houck's where the thickness is about 250 feet, the basal red shales are about 100 feet thick and contain the usual thin beds of fine-grained white limestone. The upper beds are sandstones with a layer of very impure highly cherty limestone near the supposed top. West of Barnum there are 60 feet or more of red shale lying directly on the Madison limestone. Near the upper part of this shale are two beds of limestone, the lower being 4 feet thick. At the top of the formation in this vicinity are the usual heavy beds of chert. On Otter Creek the basal member consists of 80 feet or more of light-buff massive sandstone overlain by 60 to 70 feet of deep-red shale. The upper members are buff to gray slabby sandstones with a moderate amount of chert near the top.

In the southern part of the Bighorn range the formation comprises the lower member of red shale with thin limestones, and the upper member of sandstones, cherty near the top. Near the head of Dry and Buffalo Creeks, east of Lost Cabin, the red shales are underlain by more or less brown to buff, slabby sandstone.

Age and equivalency.—From its position and stratigraphic relations the Amsden formation, together with the Tensleep sandstone, is believed to represent the Minnelusa formation of the Black Hills, the Hartville formation of the Hartville region, and the lower Wyoming in eastern Colorado.

Fossils.—Fossils are of rare occurrence. A few fragments found in the lower limestones west of Sheridan appear to be of Mississippian age, including *Menophyllum excavatum*, but in the upper cherty beds near North Branch of Crazy Woman Creek the following Pennsylvanian forms were obtained *Productus nebraskensis*, *Edmondia nebraskensis*, *Archæocidaris* sp, *Murchisonia* near M *lasallensis*, *Orthothetina* n sp, *Aviculipecten occidentalis* ?, *Pleurophorous* near P. *subcostatus*, *Euomphalus catilloides* ?, *Pleurotomaria scitula* ?, *Bellerophon* ? sp, *Fenestella* sp, *Entolium aviculatum*, *Orthonema* ? sp., *Euphemus* ? sp., and *Phillipsia major*, according to determinations by Dr. G. H. Girty. From this evidence it would appear that the lower portion of the formation is possibly of earlier Carboniferous age, while the upper portion is later Carboniferous.

TENSLEEP SANDSTONE

Relations and character.—This sheet of sandstone extends along the lower slopes of the Bighorn Mountains, usually marking the first rise above the Red Valley (see Pls XVII, *B*, and XXXIX, *A*) Its thickness varies from 50 or 100 feet in the northeastern portion of the region to over 200 feet in the east-central portion and from 250 to 300 feet to the south and west. Its most extensive outcrops are along Tensleep Canyon, from which the name was derived, and in the long mountain slopes where the dips are gentle between Trapper and Canyon creeks, and south of the North Fork of Powder River West and north of Houck's its outcrop is often 5 miles wide On the northwest slopes of the mountains, in the vicinity of Devil Canyon, its thickness diminishes to 30 feet and it outcrops as an inconspicuous ledge There are small outliers of the formation at intervals along the western slopes of the mountains and on the slopes east and west of Little Bighorn Canyon. A long narrow area occurs along a syncline in the valley of Dry Creek, east of Bald Mountain. South of North Fork of Powder River, near latitude 44°, and east of Bigtrails, it is brought into contact with the Deadwood, Bighorn, and Madison formations by faults, and it is cut out by faults and the Laramie overlap for some distance west and northwest of Buffalo and south of Bighorn. An especially fine exposure of the sandstone is in the deep gorge of No Wood Creek 3 miles north of No Wood, where its thickness is over 300 feet The predominant rock is white to buff sandstone in thick massive beds, cross-bedded and often weathering into irregular pinnacled forms. On the east side of the range, range, south of Wolf Creek, the formation is harder than on the west side and its outcrops often form high ragged cliffs and slopes along the mountain side Some features of these are shown in Pl XXXIX, *A* On the west side of the range, in the vicinity of Paintrock and Tensleep creeks, the formation varies in thickness from 75 to 150 feet, and in its thicker portions its lower part includes some softer, fine-grained sandstones and the upper member is strongly cross-bedded (see Pl XVI) At Horse Creek Canyon it is 150 feet thick South of Buffalo the formation thickens gradually from 250 to 350 feet On Little Bighorn River it is about 100 feet thick, but the amount gradually increases to 150 feet in the region west and southwest of Sheridan. The upper portion of the Tensleep sandstone often is calcareous and at many points there are one or two beds of a mixture of sand and lime sediments

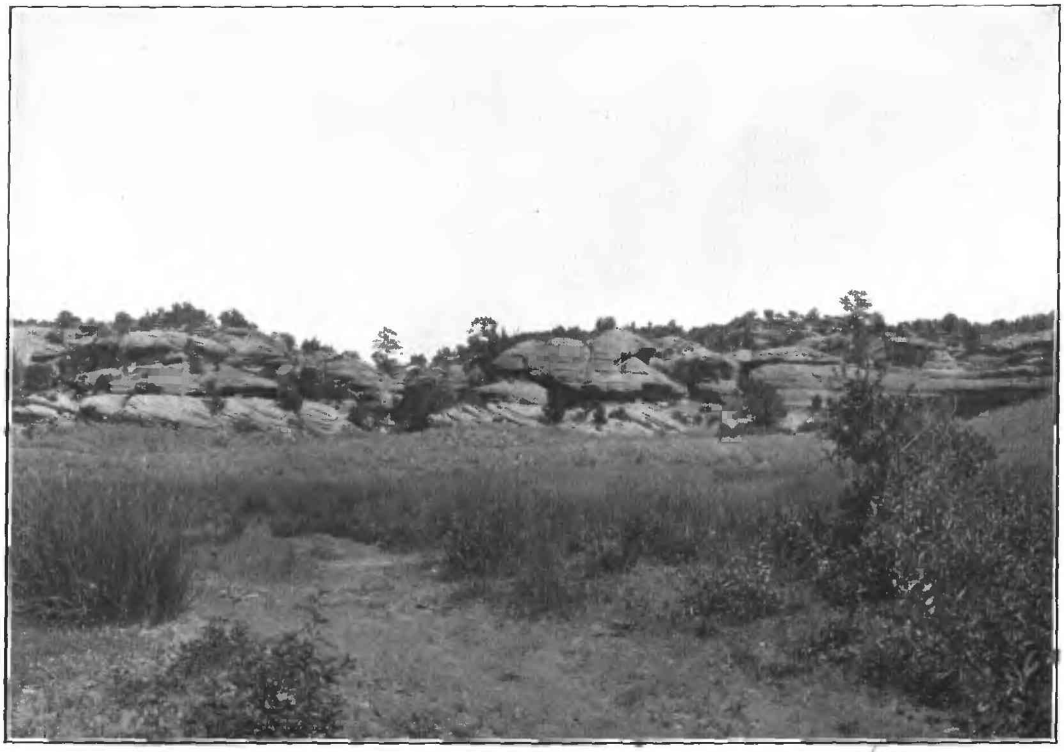
Fossils and equivalency—As stated under "Amsden formation," the Tensleep sandstone is believed to represent the upper portion of the Minnelusa formation of the Black Hills Fossils are rarely observed in the Tensleep sandstone, but a few collected from some chert nodules near the middle of the formation on the slopes west of Klondike, south of Crazy Woman Creek, were identified by Dr. G. H. Girty as *Productus cora*, *Strophostylus nanus* ?, and *Pleurotomaria* ? sp.

A. EAST END OF BIGHORN CANYON.

Looking east, out onto the plains. Walls of Madison limestone, with slopes of Amsden formation above. Photograph by J. Stimson.

B. BUFFALO CREEK CANYON AT HOLE-IN-THE-WALL.

Shows cliffs of massive cross-bedded Tensleep sandstone, surmounted by slopes of Embar formation.

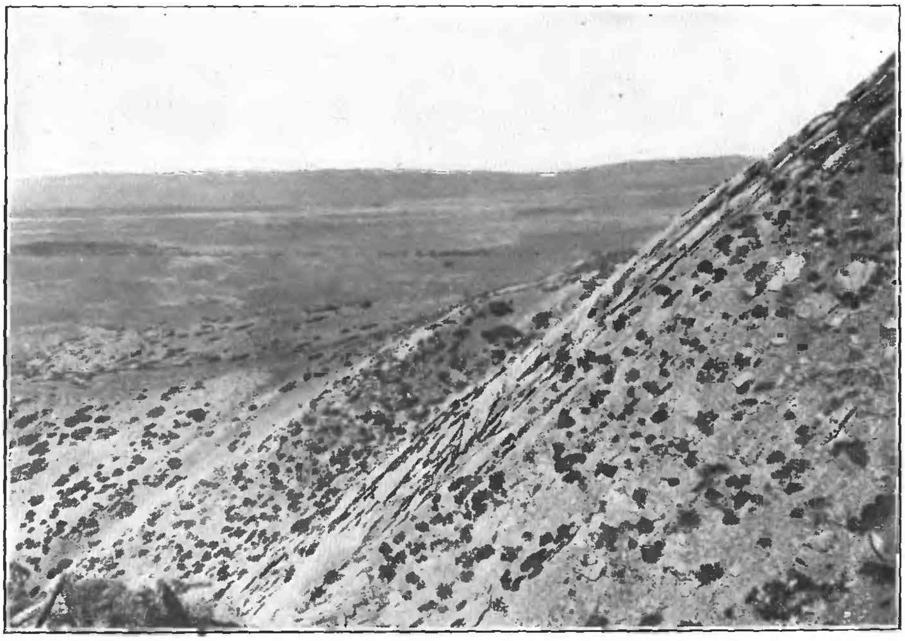


A. TENSLEEP SANDSTONE IN TENSLEEP CANYON.

Shows typical cross-bedding of upper member.

B. NORTH WALL OF TENSLEEP CANYON, 2 MILES ABOVE ITS MOUTH.

West slope of Bighorn Mountains Cliffs at top of Tensleep sandstone, underlain by Amsden beds, with thick local bed of cross-bedded sandstone, S, lying in Madison limestone, L, near base of slope, just over top of trees. Looking north



A. WEST SLOPE OF BIGHORN MOUNTAINS, 2 MILES NORTH OF SHELL CREEK CANYON.

Characteristic ledge of Tensleep sandstone on slope, and hard layer of limestone in Red Beds at foot of the mountain. Looking north.

B. TENSLEEP SANDSTONE CONSTITUTING EAST SLOPE OF LIMESTONE FRONT RIDGE OF BIGHORN MOUNTAINS.

Near mouth of canyon of North Fork of Powder River. Valley of Red Beds to left.

EMBAR FORMATION.

Relations and character.—In the southern part of the Bighorn uplift between the red beds and Tensleep sandstone is a limestone with some associated shaly and cherty beds, which, with gradual increase in thickness, is continued westward in the Bridger Range and Owl Creek Mountains. Apparently it is neither a development of the basal portion of the Red Beds nor of the calcareous sandstone which sometimes occurs at the top of the Tensleep sandstone in the region north. The occurrence of this formation is here reported for the first time and the name "Embar" is applied, from the name of the post-office on Owl Creek, a short distance south of which the formation is extensively developed. On the east side of the Bighorn Mountains the formation first appears near the West Fork of Powder River, and, on the west side, in the slopes south of Redbank. It finally attains a thickness of about 200 feet on the ridge south of Thermopolis, where it constitutes an extensive dip slope several miles wide, extending along the north slope of the Bridger Range. Prominent exposures appear in the upper canyon of the Bighorn River, which cuts deeply into this slope. Here the formation consists of 50 feet of massive limestone, underlain by calcareous shale filled with nodules and lenses of chert, a member which merges down into sandy shales and impure limestones. At the base there is a thin mass of sandstone breccia lying on the massive Tensleep sandstone. Owing to extensive faulting the formation appears only at one point on the south side of the Bridger Range, but it outcrops prominently at the southwestern termination of the Bighorn uplift, 3 miles east of Deranch. Here the limestone constitutes a line of low hogback ridges, at the base of which appear sandy and cherty shales of buff color lying on the Tensleep sandstone. A thick mass of the limestone appears in the 7,000-foot knob 6 miles northeast of Deranch, which at first sight might be mistaken for Madison limestone. Two miles south of No Wood, at the northern end of a short deep gorge of No Wood Creek, a partial section is exposed in which the Embar limestone is seen to be 10 feet thick, somewhat cherty, and lying on 10 feet of cherty shales, which extend to the top of the Tensleep sandstone. The limestone is overlain by a yellowish sandy bed, which may constitute the base of the Red Beds. At the head of West Kirby Creek the limestone is underlain by gray and reddish sands, in all about 30 feet thick. A short distance north of No Wood post-office the following section is presented:

Section on No Wood Creek 1 mile northeast of No Wood, Wyo.

	Feet.
Red beds, with 10-foot bed of limestone 100 feet from base (Chugwater)	
Limestone, light yellow, weathers in thin beds, has a layer of flint near the center, and occasional flinty concretions	10
Shale, light yellow	25
Limestone, massive, of light-gray color, with chert concretions and layers of black chert between bedding planes	20
Buff shale	0 to 2
Soft white sandstone (Tensleep)	

A mile north of this locality there is a similar section, but the basal limestone is thinner, not over 10 feet thick, is yellowish in color in its lower portion, and lies directly on the Tensleep sandstone. At the western entrance of the deep canyon, 4 miles north of No Wood, the top limestone underlying the Red Beds is 12 feet thick, massive, cherty, impure, and of yellow color. Next below are 40 feet of shales and soft sandstones, partly pale red, but yellowish near the top. They contain a few layers of limestone and lie on the Tensleep sandstone. On the east slope of Bighorn horn Mountains the formation appears at intervals in the valley of Buffalo Creek, near the Hole-in-the-wall. The limestone is 20 feet thick, with a 2-foot massive layer at the top, and with thinner-bedded slabby limestones of greenish-gray color and green shale below, lying on the Tensleep sandstone. The formation is traceable continuously northward to the Red Fork of Powder River, but gradually thins in that direction. On the anticline in Red Fork Valley, 5 miles northeast of Barnum, the Tensleep sandstone is overlain by a thin mass of limestone breccia, merging up into 6 feet of buff sands and greenish shale, which probably represent the northeasternmost extension of the Embar formation.

Fossils and age.—The limestone of the Embar formation contains large numbers of fossils in the walls of the Bighorn Canyon south of Thermopolis, but so far as observed they consist only of one mollusk, which has been identified by Dr. G. H. Girty as *Spiriferina pulchra.* This form is believed to characterize a horizon just below the so-called Permo-Carboniferous of the Wasatch Mountain region, and, as Doctor Girty correlates the latter with the Permian of the Grand Canyon section, the occurrence of these fossils in the Embar limestone suggests that this formation is equivalent to the upper Aubrey limestone of northern Arizona. There also occurs in this limestone a fenestelloid which could not be determined specifically. A few fossils were found in the Embar limestone a short distance north of the Hole-in-the-wall, but they were so indistinct that it could only be determined that they are of Pennsylvanian age.

TRIASSIC SYSTEM (?).

CHUGWATER FORMATION.

Outcrop.—Extending along the base of the steeper portions of the slopes of the Bighorn Mountains is a series of red beds which has been designated the "Chugwater" formation. They are similar to other red beds extensively developed in the Rocky Mountain region, but their thickness is unusually great, varying from 600 to 1,200 feet. The rocks are mainly soft, massive, red, fine-grained sandstones, merging into red shale, but extensive gypsum deposits and a few thin limestone beds are also included. The brilliant red color renders the formation a conspicuous feature in most portions of the outcrop area. This outcrop is narrow along the east side of the mountains in Wyoming and near Bighorn River, but it widens greatly in the district between Soap Creek and Little Bighorn River. On the west side of the range the widest outcrop areas of the formation are in the vicinity of Tensleep Creek and for some distance northward, where the width is due mainly to low anticlines flanking the main uplift. The outcrop zone is 2 miles wide on Shell Creek, but along the base of the mountain northward, where the dips are steeper, it is only a few hundred feet wide. Detached areas of Chugwater red beds cap some of the flat divides of intermediate height adjoining Devil Canyon and Trout Creek, and a long, narrow outlier is found in the syncline in Dry Creek Valley east of Bald Mountain. The outcrop zone is wide in the vicinity of Bigtrails and near Houck's, where it has an N-shaped course, owing to the anticlines east of Barnum. An extensive area appears in the Sheep Mountain uplift and one of moderate size in the anticline east of Thermopolis. The formation crosses the saddle between the south end of the Bighorns and the east end of the Bridger uplift along the valley of Bridger Creek. In this area it is extensively overlain by Tertiary deposits.

General character.—The general character of the Chugwater deposits does not vary greatly in different portions of the region. Toward the top and bottom red shales predominate, while in the middle soft sandstones and alternations of sandstones and shales are the principal features. Near the base there is invariably a thin bed of purplish-gray limestone, generally varying in thickness from 5 to 15 feet. Fifty feet or more higher there is another bed of limestone, mostly massive, of dirty-gray or buff color, in which weathering develops a characteristic porous structure. This bed has a thickness of 10 to 15 feet along the east side of the uplift and to the south, but along the west-central and northwestern slopes of the mountain its thickness increases considerably and it forms a conspicuous ledge. Toward the top of the formation there is always a succession of thin-bedded, light-colored limestones separated by red shales. These limestone bodies vary from two to four in number, and they are usually separated by from 10 to 50 feet of shales. Gypsum deposits occur in the Chugwater formation in irregular bodies in the lower and upper portions, the most persistent bed or series of beds being not far from the base. The formation attains its greatest thickness in the region northwest and southwest of Buffalo, where it measures 1,230 feet. In the region west of Sheridan the amount is 1,100 feet, but it gradually diminishes to the north, being only about 600 feet at Bighorn River. On the west side and southern portion of the range the average is about 800 feet, but it diminishes somewhat to the north, the amount being not over 700 feet near Horse Creek.

Local stratigraphy.—Along the east side of the mountains, at the base of the Chugwater formation, there are from 15 to 20 feet of red shales lying on the Tensleep sandstone to the north and on the Embar limestone to the south with perfect conformity of dip, but with an abrupt change in sediments. They are capped by 2 to 5 feet of thinly laminated, purplish limestone. Southwest of Buffalo this limestone is overlain by 30 to 50 feet of red shales, capped by 5 feet of impure limestone, which weathers to a honeycombed surface. This limestone is succeeded by red shales with several thin gypsum beds, which finally give place to soft red sandstones and red shales in the middle and upper portions of the formation. Two hundred and fifty feet below the top there is a limestone bed 6 feet thick, followed by 180 feet of red shales and sandstones and 70 feet of a succession of red shales containing three beds of limestone, the uppermost of which is 6 feet thick. Near Beaver Creek an 8-foot bed of gypsum occurs locally near the top of the formation. On Sayles and Mowry creeks, where the formation attains its greatest thickness, 1,230 feet, there is a 4-foot bed of limestone at the summit of the formation, and, 240 feet below, a bed 12 feet thick which causes a conspicuous outcrop, some features of which are shown on Pl. XVIII, *B*. On the South Fork of Rock Creek this bed of limestone is 13 feet thick and is overlain by 180 feet of red shales and soft, reddish-brown, massive sandstones. This upper series includes a thin fossiliferous limestone bed in its middle and a 3-foot bed of hard white limestone at its top. The limestone near the base of the formation is overlain by 200 feet of soft red sandstone containing much gypsum This is capped by a 20-foot bed of pure gypsum separated by a few feet of red shales from a 3-foot bed of impure limestone weathering to a brown porous rock, a member which is characteristic of this horizon. West of Bighorn the succession of upper limestones is a conspicuous feature, there being four beds from 4 to 6 feet thick separated by from 15 to 20 feet of red and purplish shales The lowest bed is generally the thickest, and it usually rises in a small, but sharp ridge. In the vicinity of Hurlburt and Little Goose creeks it is 8 feet thick and lies 180 feet below the top of the formation. In the region west and northwest of Sheridan the formation presents no exceptional features, but has the two basal and top limestones, as in the region farther south. In Red Gulch and on Pass Creek, near the Montana line, the formation has a thickness of about 800 feet, consisting of the usual bright-red sandy shales and soft red sandstones About 30 feet above the base is the usual bed of thin-bedded purplish limestone about 4 feet thick. A short distance above there is more or less gypsum and red shales and then a thin bed of impure massive limestone 10 feet thick, which weathers to a porous or cellular buff-gray rock. The top of the formation consists of red shales, containing two or three thin beds of limestone, white, fine-grained, and moderately thin bedded, of which the uppermost is separated from the overlying marine Jurassic beds by about 40 feet of red shales In Red Valley, west of Lodge Grass Creek, the following section was measured by Mr Fisher:

Section of Chugwater formation west of Lodge Grass Creek, Wyoming

	Feet
Red sandstone (overlain by Sundance formation)	60
Gypsum	6
Brick-red shale	20
Gray limestone	3
Purple shale	5
Light-gray to lavender thin-bedded limestone	12
Maroonish shale	10
White limestone, thin bedded at base, massive above	16
Purplish shale	18
Gypsum	60
Red sandstone	170
Gray and red laminated sandstone, 6 to 10 inches	6
Red sandstone	150
Gypsum	50
Porous purple limestone	4
Red shale	30
Purple thin-bedded limestone (Minnekahta)	2
Concealed (red shale probably)	30
Total	652

In the slopes 2 miles south of Bighorn Canyon the following section is exhibited:

Section of Chugwater formation 2 miles south of Bighorn Canyon, Wyoming

	Feet
Dark-red or maroon sandstone (overlain by fossiliferous Sundance sandstone)	150
White limestone series, thin beds of limestone and purple shales alternating	15
Red sandstone	125
White and purple limestone, fine-grained, thin-bedded	8
Red sandstone not well exposed, some gypsum probable (lies on Tensleep sandstone)	300
Total	598

On the west side of the Bighorn Mountains the formation is relatively uniform in stratigraphy, but some interesting local variations are presented. On Tensleep Creek the formation contains the usual two limestone beds toward the base, underlain by 100 feet of basal red sandy shales, which include three beds of gypsum, each about 8 feet thick. This series is followed by a massive, soft, red sandstone several hundred feet thick, outcropping in a prominent line of cliffs, some features of which are shown on Pl. I. These red sandstones merge above into 100 feet of red sandy shales containing near the base a 5-foot bed of hard, thin-bedded, gray limestone, while higher up there are some beds of gypsum and at the top several thin layers of slabby white limestone. On Paintrock Creek the upper Chugwater beds consist of a 16-foot limestone layer, followed by 60 feet of red sandy shales, 10 feet of gypsum, 30 feet of red shales, 100 feet of red shales with some gypsum below and thin limestone above, 2 feet of white limestone, and at the top 6 feet of red shale capped by the basal bed of the Sundance formation, which is a sandy limestone filled with fossils. Three miles southeast of Shell there is the following succession: Limestone weathering porous, several feet of gypsum, 2 feet of compact white limestone and then 50 feet or more of basal red shales, including the characteristic thin-bedded purplish limestone, which here is overlain by a 2-foot layer of conglomerate of dark-gray color containing pebbles of flinty material.

Section of lower beds of Chugwater formation on Shell Creek, east of Shell, Wyo.

	Feet.
Limestone weathering porous (under 600 feet or more of red shales and sandstones)	4
Red shale	25
Thin-bedded purplish limestone	6
Red shale	25+
Gypsum	12
Purplish sandy shale	4
Red shale (on 75 feet of Tensleep sandstone)	20

On Horse Creek the lowest limestone is 8 feet thick, thin-bedded, and of purplish tint, separated from the Tensleep sandstone by 100 feet of red shales. Between Horse Creek and Shell Creek the formation appears to thicken somewhat locally. The purplish limestone is 125 feet above the base and has a thickness of 6 feet. It is overlain by 30 feet of red shales, capped by several feet of a gray limestone which weathers porous. Kidney-shaped concretions abound here and at other localities, weathered out of this lower series. In Red Gulch east of Cloverly the lower portion of the formation is well exposed, consisting of the following beds:

Section of lower member of Chugwater formation in Red Gulch, east of Cloverly, Wyo.

	Feet.
Limestone weathering porous (overlain by about 500 feet of red shales and sandstones)	20
Green shale	15
Limestone weathering porous	6
Green shale	10
Limestone weathering porous	4
Red shale	35
Thin-bedded, purplish limestone	10
Red shales with gypsum	125
Tensleep sandstone	

On North Beaver Creek the limestone weathering porous grades up into thin-bedded white limestone, having in all a thickness of about 50 feet Below this are 85 feet of red shales, 8 feet of slabby gray limestone, in part purplish, and at the base 100 feet of red shales lying on the Tensleep sandstone. All the beds dip steeply to the west, and there are many good exposures in road cuts.

Section of Chugwater formation near Alkali Creek, northwest of Cloverly, Wyo

	Feet
Dark red shales (overlain by gray shales with Jurassic fossils)	60
White limestone with red shale partings	10
Red shale	20
Thin-bedded, fine-grained, light-colored limestones	10
Red shale	60
Red sandy shale	50
Red sandstone, some red shale	+244
Green shale	20
Massive limestone weathering porous	50
Red shale, not well exposed	40
Thin-bedded purplish limestone	6
Red shale, not well exposed (on Tensleep sandstone)	80

On the plateaus on either side of Devil Canyon and northward the lower Chugwater beds are extensively exposed, lying about level or dipping gently westward. There are from 200 to 400 feet of red shales and red sandstones remaining, underlain by 25 to 30 feet of gray limestone weathering porous, 10 feet of red shale, 6 feet of slabby limestone, and 60 feet of bright-red shale lying on Tensleep sandstone, here only about 30 feet thick.

Along the east side of the Bighorn Mountains, south of The Horn, the Chugwater formation presents a uniform succession of a lower member of red shales about 150 feet thick, containing near the base the characteristic bed of limestone and extensive gypsum deposits Above this member are about 500 feet of soft, red sandstones, which in the vicinity of Barnum and southward along the east side of the Buffalo Creek valley rise in a high, red wall facing west East of Houck's this red wall is deflected to the east and broken into a number of separated buttes by a local anticline, but south of that place it begins again and extends southward as a prominent feature as far as township 38. In all this region the basal red shales with gypsum and limestone underlie a red valley of considerable width. On and near Red Fork of Powder River, where the formation passes over a prominent anticline, there are four prominent beds of gypsum from 4 to 20 feet in thickness, separated by from 20 to 30 feet of red shales. This series is overlain by the red sandstones constituting the red wall, and underlain by 60 feet of red shales, near the base of which appears the thin-bedded limestone mentioned in most of the foregoing descriptions. Near the Hole-in-the-wall there are numerous thick beds of gypsum in the lower series East of Houck's and thence southward the red wall is capped by 6 feet of hard, dark-gray limestone, one layer of which has an irregular concretionary structure The limestone is overlain by 200 feet of buff, massive, red sandstones, with a few thin, slabby layers and occasional deposits of gray sandstone. No gypsum occurs in these upper red beds in this district The limestone capping the red wall attains a thickness of 10 feet near the southern end of the uplift, where it is overlain by about 100 feet of soft, buff and red sandstones, including one prominent, harder layer 20 feet thick near the top. Not far below this bed is a 4-foot bed of limestone. In the extensive exposures of the Chugwater formation in the vicinity of No Wood, the red shales with numerous thick beds of gypsum have a thickness of about 250 feet, and there is also a local 10-foot bed of gypsum near the top of the formation. The upper sandstone beds include several deposits of gray and buff color and two beds of limestone from 4 to 5 feet thick. About 100 feet above the base of the formation in this region there is a persistent bed of limestone from 10 to 15 feet thick.

In the Bridger uplift the Chugwater formation presents its usual characteristics, and has a thickness of about 1,000 feet. The lower half includes a number of beds of gray, white, yellow, and light-red sandstone 20 to 30 feet thick, separated by 60 to 80 feet of soft, red sandstone. In the anticline north of Thermopolis a thin limestone member occurs 150 feet below the top of the formation, and in one of the layers of this limestone large numbers of fossils occur.

Fossi s and equivalency.—Evidence as to the age of the Chugwater formation in the Bighorn region is not entirely satisfactory. From its character and stratigraphic relations it evidently represents the Spearfish and Opeche formations and the Minnekahta limestone, the latter being represented by the thin-bedded purplish limestone lying near the base of the formation. Fossils have been found in the various limestones at several localities, but unfortunately they are not sufficiently distinctive or well preserved to give conclusive evidence as to the age of the beds. Some fossils collected from the upper limestones between Columbus and Smith creeks comprise numerous forms apparently of an ostracod crustacean, numerous probable Astartes, and a few natacoid gasteropods, none of which are sufficiently distinct to indicate the age of the formation. A large number of fossils were found in the limestone, 150 feet below the top of the formation. on the east bank of the Bighorn River, 6 miles below Thermopolis, Wyo. They were determined by Doctor Girty to contain large numbers of *Natica lelia*, a species usually taken to be diagnostic of the Triassic in some portions of the West, but which is believed to be older. Apparently there is also a *Bakewellia*, and probably a *Pleurophorus*, but the remains are not sufficiently distinct for satisfactory determination. An *Aviculopecten* occurs, resembling *A. curticardinalis*, a small pectinoid of a type very characteristic of the Permo-Carboniferous of Utah. It is the opinion of Doctor Girty that, on the whole, the fauna appears to be Paleozoic, equivalent to the Permo-Carboniferous of the Wasatch Mountain section.

On Beaver Creek, east of Cloverly, the lower limestone contains an abundance of pelecypod shells more or less deformed by compression, which do not show the hinge structure and muscle scars clearly enough to be determined. According to Dr. G. H. Girty, they resemble the genus *Schizodus* of the Carboniferous, one like *S. wheeleri* and another like *S. symmetricus*, in both cases of reduced size, but they may possibly be some other genus of Mesozoic age. Near Kane numerous but ill-preserved and diminutive fossils were obtained. No generic characters are shown, and even the outline is in most cases indistinct. According to Doctor Girty, one small shell closely resembles *Myalina swallowi* of the Upper Carboniferous, but it may possibly have been a *Pteria* or *Bakewellia*, or a Mesozoic *Mytilus* or *Modiola*. Another species suggested, by its shape, *Astartella*, possibly *A. gurleyi*, but having a more projecting anterior end. At Rapid Creek this last form occurs abundantly, and with it a compressed and imperfectly preserved gasteropod, which may be *Bulimorpha*. All these suggested genera are based on characters of outlines; the fossils might be interpreted as Mesozoic forms, but Doctor Girty, and especially Doctor Schuchert, who also examined them, are inclined to believe that they are Permian, as in the similar beds in the Black Hills

It is believed from this and other evidence that the lowest portion of the Chugwater formation is Permian, and while the entire formation may be of this age, it is possible that its upper beds may include part if not all of the Triassic. Some red beds at the base of the Sundance formation, in the northern portion of the Bighorn Basin, have been found to contain Jurassic fossils, but probably they are separated from the Chugwater beds by unconformity

JURASSIC SYSTEM.

SUNDANCE FORMATION.

General relations.—This marine Jurassic representative consists of soft gray sandstones and green shales, varying in thickness from 250 to 350 feet Its outcrop extends in a narrow zone along both sides of the Bighorn uplift in the lowlands at the foot of the mountains It is continuous, except for short distances south of Bighorn and west and northwest of Buffalo, where it is cut out by faults or overlapped by Kingsbury conglomerate beds; and at the southern end of the mountains, where it is overlapped by the "Bridger" formation.

Along the east side of the mountains north of Powder River the outcrop zone is narrow, but on the west side there are areas of low dip, especially near Shell Creek, where the width of the outcrop is over a mile. North of North Beaver Creek, where the dips are steep, it is less than 100 yards wide, and this is also the case at some points west and southwest of Bighorn, northwest of Buffalo, and in the vicinity of Bighorn River on the east side of the range. In much of the region south of Mayoworth and Houck's there are wide outcrop areas. Extensive outcrops encircle the Sheep Mountain uplift, and smaller areas appear in the anticlines near Bonanza, Thermopolis, and Tisdel's ranch.

Thickness—The Sundance formation is about 400 feet thick on Beaver Creek, 450 feet south of Sisters Hill, 365 feet on Sayles Creek, 300 feet on Rock Creek, and 300 feet on Little Goose Creek On Big Goose Creek the amount increases somewhat, but farther north it diminishes again, although the amount is somewhat variable, 368 feet of beds were measured on Little Bighorn River, 266 feet on Lodge Grass Creek, and about the same or somewhat less at Bighorn River. On the west side of the mountains the formation is 325 feet thick to the southwest and from 200 to 250 feet in the region north of Shell Creek. The average thickness along the southeast side of the uplift is near 300 feet, and a similar amount appears in the northern side of the Bridger uplift.

Stratigraphy—The Sundance deposits consist largely of grayish-green shales, with masses of soft sandstone in the lower portion and thin but hard layers of sandy limestone at intervals in the higher beds. It presents many local variations in stratigraphy, and apparently throughout its course lies uncomformably on the red beds of the Chugwater formation, but without perceptible discordance of dip and usually without marked evidence of erosion. South of Sisters Hill, southwest of Buffalo, the basal member is a 3-foot bed of conglomerate, consisting of chert pebbles, some an inch in diameter, mixed with sand. This member, however, is a local feature. In the region west and southwest of Greub the basal sandy series is nearly 200 feet thick. The next member is greenish-gray shale varying from 100 to 120 feet thick, and containing thin layers of highly fossiliferous limestone, and sandy layers with abundant *Belemnites densus*, a characteristic fossil of this horizon. It occurs in cigar-shaped forms, often 3 inches in length, of dark-colored dense material, with radiated cross section. Fossiliferous limy concretions of lens shape also occur in the shales here and in other portions of the region. Near the top of the formation there are hard, sandy layers, containing many fossils, separated by shales or soft gray sandstone, the top of the formation being marked by a hard fossiliferous bed 3 to 4 feet thick, forming a small but distinct ridge in the shale slopes. West and northwest of Buffalo the basal beds are shale, which become more sandy and merge into soft sandstones south of Little Poison Creek. Next above is a thin but hard stratum of sandy limestone 3 to 5 feet thick and generally highly fossiliferous. Its thickness increases gradually southward. Next above are 75 to 100 feet of sandy beds of pale greenish gray and pale-buff color, varying from massive to thinly laminated, usually soft but sometimes including hard layers, and in places near the lower portion including some sandy shales containing *Gryphæa calceola* var. *nebrascensis*.

Section of Sundance formation just north of Beaver Creek, southwest of Greub, Wyo.

	Feet.
Hard sandy limestone with many oysters (overlain by Morrison formation)	3
Gray shale	50
Hard layer with numerous oysters	5±
Dark-gray shales, few thin sandstones and limy concretions, very fossiliferous	120
Massive white sandstone	10
Soft greenish-gray sandstones and sandy shale	115
Hard slabby sandstone with few pebbles, partings of pale greenish-gray shales, some oysters	30
Thin-bedded sandstone or greenish-gray shale	40
Thin-bedded gray sandstone	4
Hard slabby gray sandstone, few coarse sand grains. Caps red ridge	4

On Little Poison Creek, at the base, are a few inches of green shale overlain by light-gray massive sandstones 12 feet thick, merging upward into 15 feet of soft green shaly sandstone capped by a 25-foot bed of hard slabby sandstones with fossiliferous layers. In the Mowry Basin the greater part of the Sundance formation consists of shales with soft thin-bedded sandstones toward the base and two hard ledges filled with oysters at the top. Just south of Sisters Hill the formation has, at the base, a fossiliferous sandy limestone lying on 3 feet of the conglomerate above mentioned. Next above are 3 feet of soft fossiliferous sandstones, 6 feet of buff sandstone, 20 feet or more of light-gray sandy shale overlain by a 15-foot bed of soft buff sandstone, merging upward through still softer sandstones into several hundred feet of greenish-gray fossiliferous shales surmounted by a thin bed of fossiliferous, limy sandstone, with Morrison deposits a short distance above. West of Sheridan the formation presents many local variations, especially in the beds underlying the upper gray shales.

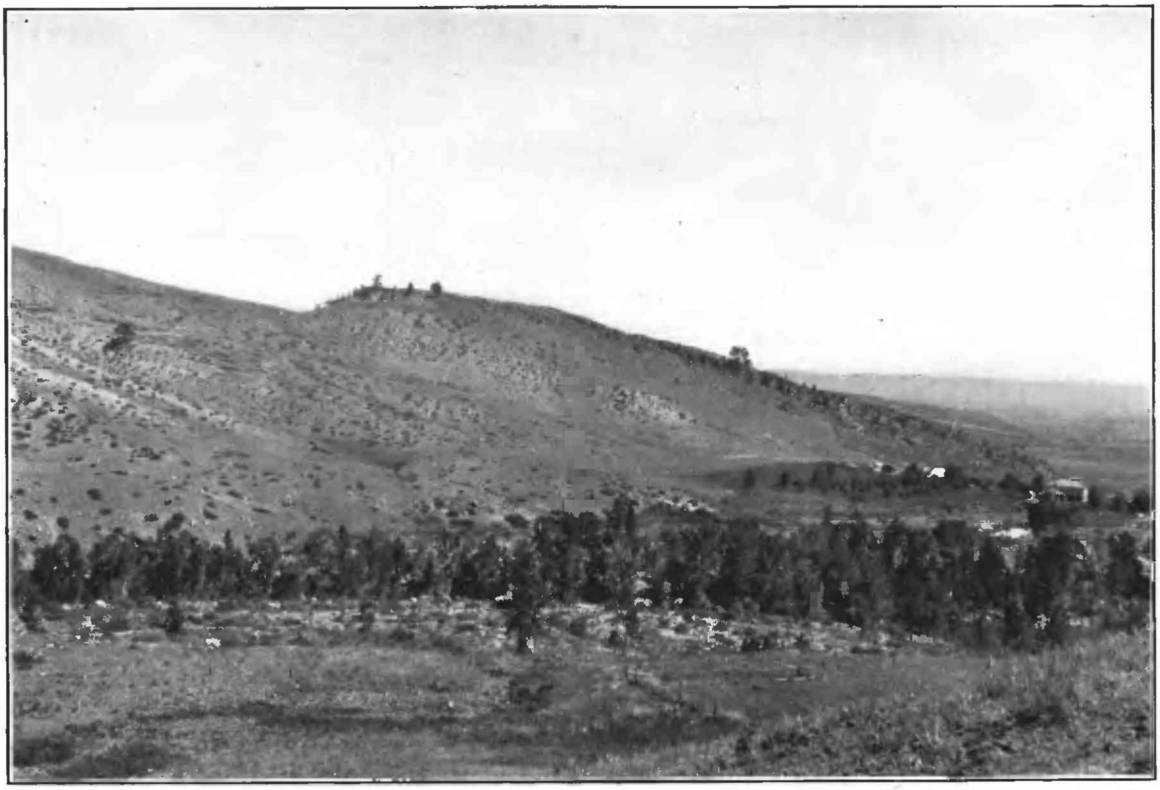
Section of Sundance beds on Big Goose Creek, west of Sheridan, Wyo

	Feet
Sandy limestone, hard ledge, very fossiliferous	8
Greenish shales with fossiliferous concretions, upper part mostly concealed by talus	175+
Buff sandstone, moderately hard	6
Fissile green shales with thin sandstone layers	25
Soft green sandy shale	8
Hard limy sandstone, fossiliferous	2
Soft buff sandstone, beds 2 to 4 inches	20
Soft white sandstone, 6-inch hard bed at top	6
Soft red sandstone	10
Green shale with *Gryphæa calceola*	25
Talus to limestone at top of red beds	30

The general features in this region are the basal shales overlain by a bed of highly fossiliferous sandstone, then sandstones and shales and a thick body of dark-gray fossiliferous shales capped by a hard bed of sandy limestone, which is overlain by a softer sandstone at the top of the formation. The basal shale, usually sandy, always contains large numbers of *Gryphæa calceola.* Its thickness averages about 30 feet, and near its base there is usually a sandy bed, which to the north often develops into a hard fossiliferous ledge 3 to 5 feet thick. At the base there are usually 2 to 3 feet of dark shale, which gives place abruptly to the red beds of the Chugwater formation. The hard bed near the base thickens to from 6 to 15 feet near Pass and Columbus creeks and is filled with fossils. This bed is also a prominent feature on the western face of the ridge just northwest of Little Goose Creek, where it dips steeply east and rises far up the steep slope as a bare sheet of limestone, a somewhat conspicuous feature in the topography. In some localities this hard layer is immediately overlain by a thick mass of dark greenish-gray shales. Hard limy sandstones are usually conspicuous at the top of the formation

Section of Sundance formation on east side of Red Gulch, south of Little Bighorn River, Wyoming

		Feet
Impure limestone (overlain by Morrison formation)		35
Light greenish-buff soft sandstone, cross bedded		20
Green shales with thin fossiliferous limestone beds		100
Soft greenish-buff massive limy sandstone, some hard layers, fossils		40
Dark-greenish shales, few sandy and limestone concretions, many fossils		120
Gray moderately hard sandstone	Prominent ledge makers	5
Dark shale		15
Hard gray to buff sandstone		6
Sandy shale with many *G calceola* in lower part		20
Gray sand		5
Dark shale (on Chugwater red shales)		2
Total		368



A. TYPICAL HOGBACK OF CLOVERLY SANDSTONE.

East side of Bighorn Mountains, northwest of Sheridan, Wyo. Ledges with trees are Cloverly sandstone; slopes to left are Morrison and Sundance shales. Looking nortn across Wolf Creek.

B. LIMESTONE LAYER IN UPPER PART OF CHUGWATER RED BEDS.

East slope of Bighorn Mountains, at North Fork of Rock Creek, northwest of Buffalo, Wyo. Ledges of Tensleep sandstone on mountain slope to left. Looking north across fault to granite ridges.

A short distance west of Lodge Grass Creek the Sundance formation exhibits the following components:

Section of Sundance formation west of Lodge Grass Valley, Montana.

	Feet.
Green to brown fossiliferous sandstones (overlain by Morrison formation)	3
Green sandy shale	20
Alternating layers of green and gray sandstones, fossiliferous at top	25
Gray sandy shale; red at base; concealed above, probably green	115
Light-gray limestone; oolite at base; thin bedded above; fossiliferous	15
Gray massive fossiliferous sandstone	6
Thin-bedded limestone	12
Gray sandy shale	60
Massive gray sandstone; very fossiliferous	10
Total	266

On the west side of the Bighorn Mountains the formation differs somewhat in local details from the exposures on the east side. Greenish-gray shales with occasional sandy and limy layers predominate, and near Tensleep Creek, in the upper 50 feet, there are three thick beds of limy sandstone filled with fossils, which have considerable topographic prominence. In the base of the formation in this region soft greenish-gray sandstones appear and, in places, a bed of dark-gray fossiliferous sandstone. Near Shell Creek and northward soft greenish-gray sandstones predominate in the lower portion, overlain by a thick mass of green shales. Some typical sections are as follows:

Section of Sundance formation on west side of mouth of Trapper Creek, south of Shell, Wyo.

	Feet.
Alternating brown sandstone and green shale, overlain by Morrison beds	20
Dark-brown fossiliferous sandstone, hard, thin-bedded	12
Dark-green fossiliferous shale with thin-bedded sandstone at base	115
Light-green sandy shale	50
Light-colored sandy clay	3
Dark-maroon sandy clay	2
Green sandy shale with numerous small oysters	20
Gray sandstone	1
Green shale (on Red Beds)	20
Total	243

Section of Sundance formation on Horse Creek, 5 miles north of Shell, Wyo.

	Feet.
Morrison shales	
Brown sandstone hard at base, soft at top, very fossiliferous	25
Soft greenish-brown sandstone	25
Green shale, many fossils, belemnites at base, large oysters above	50
Dark-brown and light-gray sandstones alternating, no fossils	20
Light-gray sandstone	25
Green shales, very fossiliferous	38
Brown sandstone, fossiliferous	1½
Light-brown sandstone, fossiliferous	2
Green shale, fossiliferous (on Chugwater maroon shale)	12
Total	198½

Section of Sundance formation on Alkali Creek, Wyoming.

	Feet.
Morrison shales	
Green shale	25
Green thin-bedded sandstone	5
Brown fossiliferous sandstone	6
Green shale with belemnites and oysters	115
Thin-bedded gray limestone	16
Green shale (on Red Beds)	75
Total	242

Along the east side of the Bighorn uplift, in the Powder River region and southward, the Sundance formation presents the same general features which characterize it in other portions of the region, but there are local variations in the details of stratigraphy. In the slopes southwest of Mayoworth the lower third of the formation is a soft buff sandstone containing two beds of hard impure limestone, the lower one being only 6 inches thick and the upper one about 2 feet thick. This series is surmounted by a 50-foot bed of massive, buff, fine-grained sandstone of moderate hardness, of which the upper beds are slabby and ripple marked; then follow 100 feet or more of green shales capped by a thin but hard bed of limestone. On Red Fork of Powder River the formation has 8 feet of buff sandstone at its base, lying on Chugwater red beds apparently with slight unconformity; then follow 50 feet of gray shales in part sandy, and a prominent ledge of massive, soft, buff sandstone similar to the 50-foot ledge above described. This sandstone layer is also conspicuous in the slopes east of Houck's, where the basal shales are 80 feet thick but are separated from Chugwater red beds by a few feet of gray sandstone. At the southern end of the uplift, in T. 38, R. 87, the ledge of massive, soft, buff sandstone above mentioned is 20 feet thick and merges downward into 10 feet of soft reddish sandstone, below which are 35 feet of soft greenish-gray sandstones and shales, 4 feet of hard, fossiliferous, impure limestone, and 60 feet of greenish-gray shale separated from the Chugwater red beds by a few feet of soft buff sandstone. The upper half of the formation consists of green shales with several thin, hard, fossiliferous layers. At the top there are usually a few feet of a buff slabby sandstone with ripple-marked surfaces.

In the extensive exposures along the west side of the valley of No Wood Creek the formation exhibits about 150 feet of upper shales, with a hard bed in the middle, underlain by a prominent bed of slabby, fine-grained, buff sandstone, here from 50 to 60 feet thick. This is underlain by 40 feet of sandy shales of buff color, separated from the Chugwater red beds by a thin, irregular deposit of gray calcareous sandstone containing black pebbles, merging downward into a dark sandy clay which appears to merge into the red shale at the top of the Chugwater formation.

Fossils and equivalency.—The Sundance formation contains abundant fossils of later Jurassic age, and it is believed to be equivalent to the Sundance formation of the Black Hills region, where the name was first applied. The following fossils occur: *Belemnites densus*, *Gryphæa calceola* var. *nebrascensis*, *Campectonites bellistriatus*, *Eumicrotis curta*, *Trigonia elegantissima*, *T. americana*, *T. conradi*, *T. montanaensis*, and *Pentacrinus asteriscus*.

CRETACEOUS SYSTEM.

MORRISON FORMATION.

General relations.—The Sundance formation is overlain by clays and sandstones of fresh-water origin, known as the Morrison formation. The thickness of this formation varies from 100 to 250 feet in greater part, and its outcrop extends along both sides of the Bighorn uplift a short distance from the foot of the mountain slopes, except at the southwestern end where it disappears beneath the Tertiary. It reappears on the north side of the Bridger uplift, especially in the anticline east of Thermopolis. It is also brought to the surface in the Sheep Mountain and Bonanza uplifts. Owing to the softness of the material, exposures are seldom extensive or complete. In the region of low dips about Cloverly and southward along Beaver Creek and south of Shell Creek the formation is spread widely by the gentle dips, and its outcrops cover large areas. Exposures of limited extent occur along Paintrock Creek, on the top of a small anticline west of Hyattville, on Powder River in the anticlines north and west of Griggs, and on South Fork of Powder River south of Tisdel's ranch. In most localities the formation forms a low saddle between the slopes of the Chugwater-Sundance ridge and the hogbacks and knobs of Cloverly sandstone.

Thickness.—The thickness of the Morrison formation is 160 feet west of Greub, 250 feet southwest of Buffalo, 150 feet northwest of Buffalo, 200 feet on Little Rapid Creek, less than 100 feet on Wolf Creek, 120 feet on Little Tongue River, 150 feet on Amsden Creek, and about 150 feet or somewhat less on the northeastern side of the mountains in Montana. On the southeast side of the mountains its thickness varies considerably, being about 150 feet east of Barnum, 100 feet east of Houck's, 200 feet near Griggs, and 250 feet on the uplift south of Tisdel's ranch. In the vicinity of Tensleep it is about 250 feet. The amount increases to the north, and on Alkali Creek, north of Cloverly, 282 feet were measured. In the vicinity of Thermopolis it varies from 120 to 130 feet.

Local characters.—The predominating material of the formation is hard clay or massive shale, varying in color from pale greenish to maroon, with darker clay at its summit, all having a peculiar chalky appearance. It includes several beds of light-gray to buff sandstones varying in thickness from 2 to 20 feet. These sandstones are usually soft, and on weathering exhibit thin, irregular bedding planes which generally have a peculiar wavy surface suggestive of incipent cross-bedding. Apparently there is conformity between the Morrison and Sundance formations, and possibly also a transition from one to the other through a few feet of greenish-gray sandstones which lie above the hard fossiliferous ledge generally marking the top of the Sundance. In the first hollow south of South Fork of Rock Creek, northwest of Buffalo, there are above this hard Sundance layer 40 feet or more of soft greenish-gray and pale-bluff sandstones which possibly should be regarded as the base of the Morrison formation or as a transition series; then follow 80 feet of clays, 15 feet of the typical sandstone above described, and at the top 30 feet of clays of maroon, buff, and greenish color below and dark above. A mile south of Muddy Creek, southwest of Buffalo, is exposed one of the clearest outcrops of the Morrison formation on the southeast side of the mountains. It exhibits at the top 10 feet of reddish shale grading down into dark shale, succeeded by 240 feet of hard, chalky clays of maroon and green tints, with occasional thin sandstone partings, and one bed near its middle, 6 feet thick, of hard, light-colored sandstone which weathers in thin beds with irregular wavy surface. Near the base of this series the clay is red. Next below is an 8-foot bed of white sandstone separated from the fossiliferous Sundance ledge by a few feet of soft gray and buff sandstones. On Little Poison Creek the features are very similar to those near Muddy Creek. A mile north of Middle Fork of Crazy Woman Creek the upper part of the formation consists of 125 feet of clays, partly maroon and partly green, with thin sandstone layers near the bottom, lying on a 5-foot ledge of light-gray sandstone underlain by 40 feet of shales and soft sandstones which overlie the Sundance. A mile south of Middle Fork of Crazy Woman Creek, 80 feet of chalky clays, light green above and maroon below, are followed by a 6 to 12 foot bed of grayish-buff sandstone containing plants and saurian bones, then 70 feet of maroon and light-green chalky clays with thin sandstone layers, then 12 to 15 feet of white, soft, massive sandstone resembling the Unkpapa sandstone which occupies a similar position in the Black Hills; this is underlain by a 20-foot series of greenish sandy clays which lie just above the hard fossiliferous bed at the top of the Sundance formation, and which possibly belong to that formation. Near Beaver Creek there are 50 feet of light-green to maroon chalky clays containing a 2-foot bed of limestone 10 feet below the top, followed in descending order by a 4-foot sandstone bed, 25 feet of clays in part maroon, several layers of sandstone, 10 feet of shale, 1½ feet of thin limestone with no fossils, 25 feet of red to maroon clays with thin sandstone layers, 2 feet of thin-bedded sandstone, 20 feet of soft, massive, white sandstone, and a few feet of clays lying on a hard fossiliferous bed in the Sundance formation.

Near Griggs, where the formation is about 200 feet thick, it contains a heavy bed of sandstone near its base. East of Houck's, where it is about 100 feet thick, there are usually two deposits of gray sandstone in the formation, and the basal shales are of reddish color. East of Barnum the basal beds are reddish and the upper beds greenish gray. In the uplift south of Tisdel's ranch there are three sandstone layers 8 to 10 feet thick in the middle and upper beds. The upper shales are reddish, medial shales green to maroon, and the lower two-fifths are green to maroon and red. The total thickness here is 250 feet.

In the region west of Sheridan the formation presents most of the characteristics above described, the clay varying in color from pale greenish gray to maroon, except at the top, where it is usually dark gray or black. Several thin beds of greenish-gray to buff sandstones occur, a persistent one near the middle being 10 to 20 feet thick and forming a small ridge. The thin bedding and the peculiar wavy surface, suggestive of incipient cross-bedding, are present. Exposures of the Morrison formation are frequent on the divides from Pass Creek to Amsden Creek, from south of Tongue River to beyond Big Goose Creek, and at intervals southward to Beaver; one of the best is on Little Tongue River. The medial sandstone is most conspicuous just north of Soldier Creek and extends to Tongue River, where it is 20 feet thick, nearly white, and massive. On Wolf Creek this sandstone lies 40 feet below the top of the formation, being overlain by that amount of green and red clay. Just south of Little Rapid Creek the interval is 70 feet, occupied by green and maroon shales 45 feet thick, capped by 25 feet of dark shales. Near Columbus Creek two beds of sandstone occurring in the clays are so hard that they cause ridges of moderate prominence. In the vicinity of Lodge Grass Creek, on the northeast side of the mountain, the basal beds are bluish-black shales, 6 to 10 feet thick, capped by 4 feet of pale brown ripple-marked sandstone, 20 feet of gray sandy clay, and 20 feet of variegated clay. Three miles south of old Fort C. F. Smith the following section was measured:

Section of Morrison formation south of Fort C. F. Smith, Mont.

	Feet.
Greenish-gray sandy shale; upper part soft (unconformably overlain by Cloverly conglomerate)	18
Buff sandstone	5
Massive gray sandstone	20
Variegated sandy shale; pale-red and green tints	75
Light-colored, fine-grained, soft sandstone lying on brown sandstone of Sundance formation	25

On the west side of the mountains the formation presents about the same features as on the east side. There are excellent exposures west and south of Tensleep, where the following section was measured:

Section of Morrison formation near Tensleep, Wyo.

	Feet.
Gray shales capped by Cloverly sandstone	40
Greenish-gray clays	100
Maroon to red clays	50
Sandstone	58
Greenish-gray to reddish sandy shale	50

In the region near Shell Creek and northward the formation presents the usual features, but south of Shell and southeast of Cloverly a massive light-colored sandstone appears near the base. South of Shell this bed is 20 feet thick and moderately hard. It is separated from Sundance beds by reddish shale and overlain by massive greenish sandy clay. Southeast of Cloverly it is of light-buff color, 40 feet thick, moderately coarse grained, and has lenses of conglomerate near the top. The pebbles of this conglomerate are dark and consist mostly of quartz. In places the sandstone is bright red, like some of the sandstone in the Cloverly formation. It is overlain by green sandy shale of lighter color than Sundance shale. A typical section of the formation, on Alkali Creek, is as follows:

Section of Morrison formation on Alkali Creek.

	Feet.
Pale-green massive shale (overlain by Cloverly sandstone)	50
Thin-bedded gray sandstone, brown on surface	15
Pale-green massive shale	5
Blue-black shale	10
Maroon massive shale	10
Variegated massive shale	45
Thin-bedded gray sandstone	6
Variegated massive shale, drab, purple, and maroon	65
Pale-green to white sandstone	6
Pale-green and maroon massive shale	85
Pale-green massive sandstone	45
Red sandy shale (lying on Sundance formation)	40
Total	382

In the region north of Thermopolis the formation contains, near its middle, a massive fine-grained, soft, greenish-gray sandstone 50 feet or more in thickness. Above this are 40 feet of sandy shales, some dark maroon in color, then 10 feet of very dark conglomerate loosely cemented, and at the top about 10 feet of highly carbonaceous shale merging into dirty-buff clay.

Fossils and equivalency.—From its character and stratigraphic relations the Morrison formation is believed to be the same in the Bighorn uplift as in the Black Hills and Rocky Mountain regions to the east and south. It contains fossil saurian remains supposed to be of the same fauna as those found in the other regions mentioned. Opinions are divided as to whether these are of late Jurassic or early Cretaceous age. A few plants observed southwest of Buffalo are not sufficiently well preserved to throw light on the age of the beds. From stratigraphic evidence in other regions, the Morrison formation is provisionally classed in the early Cretaceous.

CLOVERLY FORMATION.

General relations and character.—The Cloverly formation consists of sandstones and sandy clay supposed to represent the formation usually referred to as Dakota sandstone. It has a thickness varying generally from 100 to 200 feet and lies on the Morrison clays throughout its course. Its outcrop zone extends along both sides of the Bighorn Mountains, its hard sandstone often giving rise to a small hogback ridge, or to knobs on the divides between the principal creeks and rivers flowing out of the mountains. The clay member is rarely well exposed and often the sandstones are soft, so that their outcrop is inconspicuous. A typical view of the Cloverly hogback is given in Pl. XVIII, *A*.

The most extensive exposures are in the vicinity of Cloverly, the locality from which the formation was given its name. Here the dips are low and numerous outcrops appear in cliffs and slopes. The formation is conspicuous in the slopes south of Shell Creek, from near Shell to Sheldon's ranch. It is also exposed with considerable prominence in the three small anticlines west of Hyattville, and in the ridges and slopes north and south of that settlement. Good exposures appear south and west of Tensleep, all along the west side of No Wood Valley, in the flexures north and east of Thermopolis, and at intervals along the east side of the mountain in Montana and Wyoming. The sandstone which constitutes the lower half of the Cloverly formation ordinarily is a coarse-grained, buff or dirty-gray, cross-bedded massive sandstone, ranging from 30 to 50 feet in thickness in most localities. A notable exception is in the region just north of Little Tongue River, where there is a local increase to about 200 feet. On West Twin Creek the amount is about 100 feet. Much of it is hard, but in places the rock readily disintegrates. As a rule its basal portion is somewhat conglomeratic and, though it appears not to be separated from the Morrison formation by an unconformity, there is an abrupt change from the shale of the one formation to the coarse sandstone or conglomerate of the other. This feature, however, is general wherever coarse deposits succeed fine ones. Nearly every outcrop of the sandstone bears a few pine trees which do not occur on the adjoining formations.

The upper member of the Cloverly formation consists of clays, mostly of ash-colored and purplish or reddish tints, varying from 20 to 50 feet in thickness. Some portions are pale green and maroon, somewhat similar to the Morrison clays in character. At the top of the formation, in some localities, a few feet of massive light-colored sandstones appear. In portions of the area, especially on the east side of the mountain, the base of the formation is a light-colored sandstone, with streaks of dark shale and impure coal similar to those which occur in the base of the Lakota formation in the Black Hills region, but offering no promise of economic importance.

Local features.—In the region southwest of Buffalo the formation varies greatly in thickness and prominence. On Beaver and Crazy Woman creeks the sandstone averages about 30 feet thick. The greatest thickness observed is southeast of Sister Hill, where, for some distance, it is 60 feet. Northwest of Buffalo the sandstone varies from 10 feet on South Fork of Rock Creek to about 30 feet 2 miles farther south. In the region west of Sheridan the formation appears mostly in small, detached knobs due to the lower sandstone, with occasional small outcrops of reddish or ash-colored clays above. One of the best sections is at the foot of a low knob on the summit of the first ridge east of Little Rapid Creek. Here the sandstone has a thickness of 22 feet, but is too soft to rise above the slope. It is overlain by 30 feet of pale-green and maroon clays, grading upward into dark shales with thin-bedded, brown sandstones at the base of the Benton formation. To the north the formation contains two and possibly three beds of sandstone, separated by shale and overlain by 40 feet or more of greenish and reddish clays of the upper member. On Big Goose Creek the basal sandstone member is 30 feet thick, but about 30 feet above and 30 feet below are additional sandstone beds 10 to 15 feet thick, separated by dark shale. East of Little Tongue River, for several miles, occur exposures of 45 feet of light-colored sandstones, parted by a 3½-foot deposit of highly carbonaceous shale which has been prospected for coal at several points. Farther north the sandstone rapidly increases to a thickness of about 200 feet and a considerable mass of conglomerate is included at its base. On West Twin Creek the sandstones have a thickness of about 100 feet and they are overlain by a thick body of clays. On West Pass Creek the formation is particularly well exposed for a thickness of about 250 feet. The clearest exposures are in the slopes a few rods east of the creek. The sandstone gives rise to a prominent ledge bearing a characteristic clump of small pine trees. It is overlain by gray clays merging upward into a series consisting of white sandy clay, maroon clay, light ash-gray clay, and a thin bed of light-gray clay, nearly white at the top. Above this are dark-gray clays, containing more or less sandstone, which appear to belong to the Benton formation. From Wolf Creek northward there is often a bed of buff sandstone capping the clay member. It is about 10 feet thick between Wolf Creek and Little Tongue River, and it appears again at Smith Creek. South of Columbus Hill and north of East Twin Creek it is about 6 feet thick, but occurs in detached areas.

In the vicinity of Little Bighorn River and Lodge Grass Creek the sandstones are in two beds separated by variegated clays of red, dark-green, and maroon tints. The upper clay member appears to be only about 20 feet thick near Lodge Grass Creek, but it increases to 100 feet near Bighorn River. In the section 4 miles south of the river the basal bed consists of 15 feet of massive, pebbly, cross-bedded sandstone which weathers to a dark-buff color. It is overlain by 50 feet of buff and gray sandstone, cross-bedded in its lower portion and with hard layers at the top. This is followed by a considerable thickness of highly colored sandy shales, mostly covered by talus and capped by 25 feet of massive buff sandstone, which extends to the base of the black Benton shales. Between the Lodge Grass and Little Bighorn the section consists, in ascending order, of 85 feet of gray massive sandstone, cross-bedded, with rusty-red streaks and maroon tints, 20 feet of reddish sandy shale, 15 feet of gray, massive cross-bedded sandstone, 6 feet of gray shale, capped by 1 foot of brown sandstone at the base of the Benton black shales.

On No Wood Creek, south of Tensleep, the formation consists of a massive light-colored sandstone about 40 feet thick, overlain by 30 to 60 feet of light-colored shale, mostly massive, and at the top a thin bed of harder buff to reddish-brown sandstone 8 to 10 feet thick. A mile west of Tensleep the basal sandstone is nearly pure white in color, coarse grained, and cross-bedded. The overlying shale and clay are 60 feet thick and at the top are 8 feet of sandstone varying in color from white to buff and brown.

In the vicinity of Hyattville the following members are exposed: At the base 40 feet of buff cross-bedded sandstone overlain by 130 feet of clays, reddish near the bottom, greenish and sandy higher up, maroon toward the top, and gray and sandy at the top. These clays are overlain by a 15-foot bed of hard, buff, partly massive sandstone succeeded abruptly by dark Benton shales with thin, brown sandstone layers.

In the anticline north of Sheldon's ranch 52 feet of the formation are exposed, consisting of 15 feet of olive-green sandstone lying on Morrison beds, 20 feet of soft sandstones of a deep chocolate-brown color, 20 feet of soft gray sandstones, and, at the top, 15 feet of massive brown sandstone, all weathering into badlands. West of Shell the formation consists of brown sandstone at the top, maroon sandy shale in the middle, and massive buff sandstone at the base. In the vicinity of Cloverly the formation varies in thickness from 50 to 125 feet, and to the east and north of that place it consists of sandstones which outcrop extensively in cliffs of massive buff-colored beds, mostly of moderately coarse-grained material. To the west the middle and lower portions of this sandstone change to a maroon color and some clay is intermixed with the sand. This rock weathers into badlands.

Section of Cloverly formation 1½ miles west of Cloverly, Wyo.

	Feet.
Light-buff sandstone (overlain by Benton shale)	10
Tan-colored sandstone	10
Maroon clay	.4
Reddish and tan-colored sandy clay	10
Drab sandy clay	10
Deep-maroon sandy-clay	20
Hard tan-colored sandstone	3
Deep-maroon to purple variegated clay	12
Lenses of maroon sandstone	3
Deep-maroon sandy clay	20
Olive-green, soft, cross-bedded sandstone, with hard layers (lying on maroon and drab-gray Morrison shale)	11
Total	112

Along the east side of the mountains south from Mayoworth the formation presents considerable local variation, especially in thickness, which diminishes to 20 or 30 feet east of Barnum. The purplish and buff-colored sandy clays in the upper portion of the formation thicken and thin irregularly, and the basal sandstone is usually conglomeratic for a moderate thickness. At the top there is generally a thin bed of sandstone, varying from brown to light gray in color, which is possibly a basal member of the Benton. South of Okie's store the formation consists of 20 feet of buff sandstone, in part cross-bedded, overlain by 35 feet of sandy shales, greenish buff and pale maroon below, capped by 4 feet of brown sandstone. On the east side of Willow Creek, east of Houck's, there is much conglomerate in the base of the formation and purple and buff clay at or near its top. In the small uplift south of Tisdel's ranch, east of the South Fork of Powder River, the formation consists of 40 feet of sandstone, slabby at the top, coarse and massive in the middle, and conglomeratic at the base. In the vicinity of Bighorn River, north of Thermopolis, there is at the base 35 feet of massive hard sandstone of light-gray color with some conglomeratic streaks, which is overlain by 20 feet of softer buff sandstones, 30 feet of purple sandy shales, and at the top about 6 feet of slabby dark-buff sandstone, which weathers to a brown color.

Equivalency.—The Cloverly formation is believed to represent the Lakota sandstone, Fuson formation, and Dakota sandstone of the Black Hills region. Apparently the Dakota member is not well developed, or possibly is represented in transition shale beds and thin sandstones at the top of the formation. However, as there is apparently no unconformity between the Cloverly and Benton sediments, some representative of the Dakota must be present. So far the formation has not yielded any fossils which throw light on its age, for only a few fragments of leaves and pine needles have been observed. On the basis of the above correlation it represents the later deposits of the lower Cretaceous and the earliest deposits of the upper Cretaceous.

COLORADO FORMATION.

General relations and character.—The black shales of the Colorado formation extend along the plains on either side of the Bighorn Mountains. They vary in thickness from 1,400 to 2,200 feet in greater part, the amount generally being smaller on the west side of the mountains. The outcrop zone is of variable width, owing mostly to variations in the dips in different portions of the region. South and west of Buffalo and Sheridan the outcrop is seldom half a mile wide, and it is cut out for some distance by the faults and the overlap south of Bighorn and west and northwest of Buffalo. On either side of Little Bighorn and Bighorn rivers the outcrops are wide, amounting to nearly 5 miles on the Bighorn. Along the west side of the mountain the formation lies in synclines and the area west of Cloverly is nearly 10 miles wide.

While the formation consists mainly of shale, it also includes occasional sandy deposits and concretions. A prominent member in its medial part consisting of hard gray shales and thin-bedded, fine-grained sandstones has been separated as the "Mowry beds." This member lies somewhat above the middle of the formation, and, owing to its hardness, usually forms prominent ridges and buttes. One prominent landmark of this character near Slack is known as Columbus Peak. High ridges west of Cloverly and extending from Sheldon's ranch to beyond Hyattville consist of this member, together with some overlying sandstones. In the shales near the upper part of the formation occur large, oval, limy concretions, weathering to a brown color and containing *Prionocyclus, Prionotropis,* and allied ammonites, a characteristic horizon at the top of the Benton group (Carlile formation) throughout the central-western United States. At the top of the formation are 200 feet or more of gray shales supposed to represent the Niobrara formation

Toward the base of the formation is a series of shales containing considerable iron and thin layers of rusty sandstone, of which one horizon about 100 feet above the base is characterized by the occurrence of globular concretions, mostly from an inch to 1½ inches in diameter, with radiated internal structure. They consist of impure phosphate of lime which shows remains of a crystalline form, indicating that they are replacements of the mineral marcasite.

The thickness of this "rusty series" is usually about 200 feet. It is succeeded by 600 feet or more of black shales, with occasional concretions and thin sandstone layers. This is surmounted by the Mowry beds, from 150 to 300 feet thick. These beds weather to a light-gray color and the sides of the numerous joint planes by which they are traversed are usually yellowish. Most of these layers contain large numbers of impressions of fish scales. On the west side of the range the upper Mowry beds develop into alternations of coarser, slabby sandstones of dark-gray color, most of them so hard that they have considerable topographic prominence. Higher in the series there are some softer, more massive, lighter-colored sandstones. The top member varies in thickness from 400 to 600 feet and consists largely of gray shales, with the ammonite-bearing concretions in their middle portion.

Thickness and local features.—The Benton formation varies greatly in thickness. On Sayles Creek 1,900 feet were measured, but the amount diminishes to the south to an average of about 1,400 feet in the region southwest of Buffalo and only 1,000 feet in the vicinity of Rock Creek, northwest of Buffalo. Possibly, however, this diminished thickness is due partly to faulting and crushing. Southeast of Sisters Hill there is included in the lower portion of the formation a local 10-foot bed of white, massive sandstone, which again outcrops in a low but conspicuous knob a short distance south of the Sisters Hill road and again in the slope a mile south of Muddy Creek. The position of the base of the Mowry beds in this region was found to vary considerably. The thickness of the lower members of the formation below the Mowry varies from 750 to 850 feet from Sayles Creek southward, but is only about 600 feet near South Fork of Rock Creek. The bed of white sandstone above referred to is 15 feet thick and lies 270 feet below the Mowry 1 mile south of Muddy Creek, and is from 8 to 15 feet thick, and lies 350 feet below the Mowry southeast of Sisters Hill. The intervening beds are dark shales. Southwest of Bighorn the thickness of the Benton formation is about 1,250 feet, but the amount increases gradually northward, attaining about 1,900 feet near the Montana line. The Mowry beds average about 200 feet in thickness, presenting the characteristics above described. On Hurlburt Creek they lie 700 feet above the base of the formation; on Wolf Creek, 1,000 feet; on Little Rapid Creek, 850 feet; and on West Twin Creek, 1,400 feet.

On West Twin Creek, where the formation attains a thickness of about 1,900 feet, it presents the usual features of stratigraphy. At the base are the "rusty beds" of shales, with several thin brown and buff sandstone layers and the globular concretions near their base. The dip is 24°, and the slopes are covered by talus, but there is a thickness of about 500 feet extending to a thin bed of buff sandstone. Those beds are succeeded by 850 feet of black shale containing a 6-foot local bed of buff sandstone 600 feet below the top, a characteristic feature of this horizon. The black shales are surmounted by 150 feet of the Mowry member, dipping 13° E., and forming a high ridge on the east slope of which are 400 feet or more of gray shales with oval concretions in their middle part. These concretions are of buff color, 1 to 3 feet in diameter, and contain *Prionocyclus woolgari*, believed to mark the top of the Benton group.

On Rotten Grass Creek the Mowry is about 200 feet thick and lies about 1,000 feet above the base of the formation. Near Soap Creek the dark shales overlying the Mowry are about 200 feet thick, then follow 20 to 25 feet of shales with brown concretions 1 to 6 feet in diameter containing ammonites. There is a similar occurrence of these fossiliferous concretions several hundred feet higher up.

On the west side of the Bighorn Mountains the formation contains a thicker mass of harder and coarser deposits in its middle. The thickness west of Shell and Cloverly is about 1,400 feet. The salient features west of Cloverly are as follows: At the base, lying on buff sandstones of the Cloverly formation, are about 100 feet of dark-gray to black shales with layers of thin brown sandstone weathering to a rusty color. The shales usually begin abruptly on top of the Cloverly sandstone, but without sign of unconformity. The characteristic globular concretions averaging an inch in diameter occur in a few feet of the lower shales about 60 feet above their base. Above this basal "rusty" series are about 200 feet of black fissile shales, mostly of splintery texture, capped by 25 feet of hard sandy shale and thin-bedded dark sandstone representing the Mowry member of the east side of the mountains, and similarly weathering to a light-gray color. These beds merge upward into 30 feet of dark shales and then comes a series of alternating shales and hard slabby sandstones capping and extending down the western slopes of a high ridge. The sandstone layers are from 6 inches to 3 feet thick, of dark-gray and light-blue-gray color. This series probably represents the upper part of the Mowry. At its top is an extensive bed of light-colored soft sandstone 10 feet thick. This is overlain by several hundred feet of dark-colored soft shales, with a few black concretions, succeeded by light-colored shales with several sandstone layers, and then 100 feet of sandy buffish-colored shales with brown concretions containing *Metoicoceras gibbosus*, *M. whitei* Hyatt, and *Inoceramus fragilis*. Then follow 200 feet of gray unfossiliferous shales, believed to be the top of the formation. The total thickness is about 1,400 feet.

On either side of the syncline south of Sheldon's ranch the Colorado formation forms a ridge of considerable prominence, which extends far to the southeast. A section of the eastern ridge not far south of Shell Creek shows a succession of 550 feet of dark shales at the base, 80 feet of light-gray fissile shale, 110 feet of alternating layers of hard blue sandstone and shale, 250 feet of gray shale, 30 feet of thin-bedded rusty sandstone, partly concretionary, 25 feet of white sandstone, and 30 feet of shale containing *Metoicoceras*, followed by gray and yellowish shales believed to be the top of the formation—1,275 feet in all.

In the region south of Mayoworth there develops in the upper part of the Colorado formation a bed of sandstone which attains considerable prominence in the Powder River district. It gives rise to a ridge and west-facing escarpment south of the Middle Fork of Powder River near Griggs. In the vicinity of Willow Creek it lies about 150 feet above the Mowry beds, and is 60 feet thick. The rock here is a massive buff to gray sandstone, containing some iron concretions, especially near the top. Next above are 150 feet or more of dark shales with scattered buff sandy concretions in the upper beds, apparently at the same horizon as those containing *Prionocyclus* in other portions of the uplift. These upper shales are capped by another heavy bed of sandstone, which appears to represent the Niobrara or the base of the Pierre. In the uplift southeast of Tisdel's ranch the beds underlying this last-mentioned sandstone, here 40 feet thick, are as follows:

Section of Colorado formation 2 miles south of Tisdel's ranch, Wyoming.

	Feet.
Dark shale, with a few thin sandstone layers	150
Gray shale, with buff sandy concretions, containing *Prionocyclus woolgari*	30
Gray shale	60
Hard buff sandstone	3–10
Gray shales, with several layers of brown sandstone	50
Dark shales, with 2-foot bed of Bentonite near base	350
Mowry beds	150
Dark shale (lying on Cloverly sandstone)	500

Southeast of Griggs the sandstone member varies from 20 to 40 feet thick, and some portions are conglomeratic. It is overlain by about 200 feet of shales containing in their middle portion buff concretions carrying *Prionocyclus*. At the southern end of the Bighorn uplift, in R. 86, T. 38, the Mowry beds, 100 to 125 feet thick, are overlain by about 1,000 feet of dark shales containing several layers of sandstone from 3 to 6 feet thick, and near the top a bed of hard gray sandstone 15 to 30 feet thick. Under the Mowry beds is a thick mass of black shales containing, near the bottom, a thick bed of hard, gray, slabby sandstone, which appears to continue for some distance north.

Along the draw just north of Willow Creek, 11 miles due south of Griggs, the following succession was measured, approximately:

Section of Colorado formation in T. 41, R. 82, near Willow Creek, Wyoming.

	Feet.
Dark shale, with bed of soft sandstone, with several beds of concretions	200
Gray to white sandstone, massive, cross-bedded, with brown sandstone concretions	40
Dark shales, mostly fissile, contains bentonite deposits	250
Mowry beds	140
Black fissile shales	140
Gray shales, with occasional thin brown sandstone layers	150
Brown slabby sandstone	6
Gray shales, with brown sandstone layers, lying on Cloverly sandstone	100

On the north slopes of the Bridger uplift there is the usual succession of black shales, Mowry beds, and several hundred feet of shales and sandy shales containing thick beds of sandstone. In the vicinity of West Kirby Creek several layers of massive gray sandstone occur in the basal shales. Toward the top of the formation there is a prominent ledge of brown sandstone 40 feet thick. This is overlain by shales containing occasional concretions, in one of which was found the distinctive *Prionocyclus woolgari*. They merge upward into light-colored shales strongly suggestive of the Niobrara in appearance. The Mowry beds in this region are 150 feet thick and are immediately underlain by 50 feet or more of black shale lying on a 12-foot bed of slabby sandstone.

Niobrara beds.—The only evidence of the existence of these in the Bighorn region is the apparently continuous sedimentation from the Benton to the Pierre shales. The deposits are mainly gray shales, evidently containing little carbonate of lime, so that they lack the characteristics which distinguish the Niobrara formation in the region to the south. On the west side of the mountains some portions of the shales weather to a yellowish color, which is a suggestive feature. In the Powder River region there appears at the base of the Pierre shale a prominent bed of sandstone, which lies immediately above the upper Benton shales, or *Prionocyclus* horizon, and which may possibly represent the Niobrara. It reappears prominently in the Owl Creek Mountains, near the west end of which it contains numerous fossils, which may possibly indicate a shallow-water fauna of Niobrara age. On the main road to Thermopolis, on Kirby Creek, in township 42, the sandstone at this horizon is 4 feet thick and overlies 30 feet of calcareous shale weathering to a light-yellow color, which is strongly suggestive of the Niobrara. The thickness of beds between the highest Benton and the lowest Pierre fossils is about 200 feet and no organic remains have been found in this interval. Small areas of the uppermost beds cap the high summits southwest of Cloverly.

Equivalency.—The Colorado formation in the Bighorn region is equivalent to the Benton and Niobrara groups in the Rocky Mountain and Great Plains region farther south and east, but its limits are somewhat indefinite, owing to the almost general absence of separable Dakota sandstone at its base. The Benton group in other regions consists of Graneros shales, Greenhorn limestone, and Carlile shales, but these subdivisions have not been found in the vicinity of the Bighorn Mountains, owing mostly to the lack of development of the Greenhorn limestone. In the Black Hills region and southward the Mowry member occurs considerably below the middle of the Graneros shale, while in the Bighorn uplift it lies only a few hundred feet below the top of the formation, so that in this interval there are the representatives of the upper Graneros, Greenhorn, and Carlile deposits of other regions. The occurrence of the concretions, with *Prionotropis* and other ammonites appears to indicate the presence of the member which is characteristic of the top of the Carlile formation in other regions, and as there is no evidence of a hiatus in any portion of the Benton formation in the Bighorn region, it is reasonable to believe that the subdivisions are presented here, but in an attenuated form and with the Greenhorn limestone horizon not characterized either by lime sediments or the distinctive fossil *Inoceramus labiatus*.

Fossils occur rarely in the Colorado formation in the Bighorn region. The ammonites and a few flat *Inocerami* in its top are the principal remains, except the large numbers of fish scales, bones, and teeth in the Mowry member.

PIERRE SHALE.

General relations and character.—A thick mass of dark-gray shales, with abundant Pierre fossils, extends along both sides of the Bighorn Mountains and occupies the wide syncline of the Bighorn Basin. West and south of Buffalo and Sheridan for some distance, where the dips are moderately steep, the outcrop zone of the formation is narrow, but approaching the Montana line it begins to widen, and on Lodge Grass Creek and Little Bighorn River it attains a width of 20 miles. The area in Montana has not been studied in detail, but the formation was observed to consist of the usual thick succession of dark-gray shales with occasional thin beds of sandstone. In the Powder River region the Pierre area gradually widens southward into the broad basin, which extends from the south end of the Bighorn uplift to the North Platte River near Casper and westward. In the southeastern corner of the Bighorn Basin, west of the southern end of the Bighorn Mountains and north of the Bridger Range, the formation outcrops in a zone of low plains from 3 to 8 miles in width.

In the region west of Sheridan the Pierre shale appears to have a thickness of about 3,500 feet, and it presents but little variety in composition. Concretions of impure carbonate of lime occur, especially toward the base, and sometimes they are sufficiently numerous to form low ridges. They are of oval shape, varying in diameter from a few inches to 6 feet, the greater number of them being between 2 and 4 feet. Some are of compact material and others consist largely of cone-in-cone. In the region north of Wolf Creek a thin layer of buff sandstone occurs about 1,000 feet below the top of the formation and persists for some distance, attaining in its maximum development a thickness of 20 to 30 feet. It is partly concretionary. In the region north of Columbus Peak there is a very characteristic zone of lens-shaped, calcareous concretions, which extends into Montana, its outcrop passing just southwest of Slack. An irregular bed of buff sandstone, in part concretionary, occurs toward the top of the formation. The Pierre shale is cut off abruptly by the fault south of Bighorn, and it does not appear again until Rock Creek and Mowry Basin are reached. On Sayles Creek, where the beds stand nearly vertical, the thickness is about 2,000 feet, and, aside from concretions, the only interruption in the succession of dark shales is a 12-foot bed of grayish-buff sandstone about 500 feet above the base of the formation. West of Buffalo the formation is again cut out by faults and the overlap of the Kingsbury conglomerate. Southwest of Buffalo it extends along the east side of the mountain for many miles. Its outcrop zone gradually increases in width to over 3 miles on Beaver Creek. In this area there is usually a thin bed of brown sandstone about 600 feet below the top of the formation.

Fossils.—The Pierre shale contains abundant fossils, which are characteristic of the formation in other regions. They occur mostly in concretions, and many species are represented.

PARKMAN SANDSTONE.

Overlying the Pierre shale there are several hundred feet of sandstone supposed to represent the Fox Hills formation. It will be designated Parkman sandstone, from the station of that name. At most localities the sandstone begins abruptly with only a few feet of beds of passage, but in others the lower limit is less definite. Owing to the relative hardness of the material, it usually forms a low ridge or line of knobs, which rise conspicuously above the adjoining shale slopes. This ridge extends continuously from far north of Montana southward to Little Goose Creek, where it is cut off by the fault south of Bighorn. It passes a short distance west of Parkman and Dayton and crosses Big Goose Creek 12 miles southwest of Sheridan. Its width near the State line is nearly a mile, for the dips are low, but, with the increasing rate of dip southward, it gradually narrows, and on Little Goose Creek it is only about 300 feet.

The material is a very massive soft sandstone of buff color, with dark, hard concretionary portions. Its thickness averages about 350 feet. South of the fault it appears again on Rock Creek and in Mowry Basin northwest of Buffalo, and southwest of Buffalo in an outcrop, which continues far southward with increasing thickness. The upper limits of the formation are indistinct and apparently it grades into the overlying Piney formation. In the region south of Buffalo there are some overlying shales which may belong to either formation, so far as any definite evidence is concerned. The formation was not examined in the region west of the Bighorn Mountains.

The following fossils have been collected from the Parkman formation and determined by Mr. T. W. Stanton:

Cardium speciosum M. & H.
Ostrea glabra M. & H.
Avicula linguiformis E. & S
A. nebrasca E. & S.
Liopistha (Cymella) undata M. & H.
Thracia subgracilis Whitfield.
T. subtortuosa M. & H.
Tellina equilateralis M. & H.
Lunatia subcrassa M. & H.
Spæriola? cordata M. & H.
Leptosolen.
Cylichna.
Baculites.
Prima.
Leda, and
Modiola.

PINEY FORMATION.

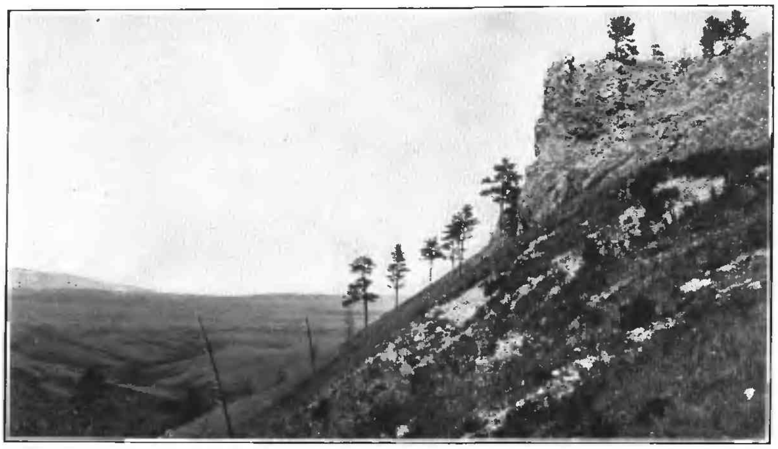
The name Piney formation is proposed for the lowest formation of the thick series of freshwater sandstones and shales of later Cretaceous age, formerly designated "Laramie," lying in the great basin adjoining the Bighorn uplift. The name is derived from Piney Creek, northwest of Buffalo.

It is difficult to separate the base of the Piney beds from the top of the Parkman, for apparently one formation grades into the other, at somewhat different horizons in different portions of the area. In the steeply dipping strata southeast of Buffalo the Piney formation has a thickness of about 2,000 feet. The lowest beds are sandstones and shales of light color, and the upper members consist of white, red, and green sands and sandstones, alternating with layers of green and yellow clays, dark shales, and iron concretions, the latter composed of sand cemented by iron oxide. This formation is extensively exposed along the north side of Rock Creek southwest of Lake De Smet, also on the west slope of the high ridge south of Johnson Creek, and notably in the slopes a mile southeast of T. A. ranch, where it forms badlands. Here the beds are dark-gray, green, and black shales, with an occasional layer of brown sandstone, which in places is of concretionary nature. This series is more extensively exposed here than elsewhere, having a thickness of at least 1,500 feet and dipping 20° E. Two miles southeast of Sisters Hill the beds lying between the Parkman sandstone and the sandy members in the Piney formation are a series of light and dark greenish-gray to rust-colored shales, with occasional 4 to 6 inch layers of rust-red sandstone. They have yielded no fossils and may belong to the Parkman formation.

In the vicinity of Parkman, where the Piney formation is most extensively exposed, it consists of alternating greenish and black coaly shales with an extensive bed of pale greenish-gray sandstone at the base and several layers of massive sandstone higher up in the hills east of the railroad. The sandstone which is regarded as the basal bed is 8 feet thick and has been quarried to some extent for building purposes one-fourth mile south of Parkman on the east side of the railroad. It is overlain by dark shales with coal streaks and numerous plant fragments. Owing to the low dip in this area the outcrop of the beds is wide. On Smith Creek, where the dip is 30°, the upper beds of the Piney formation comprise 100 feet of purplish to rust-colored massive sandstone, underlain by 100 feet of greenish-blue clay and this by a second bed of sandstone which forms a low ridge. The thickness of this bed could not be ascertained; below it there are two heavy ledges which outcrop in low ridges west. The total thickness in this section is about 2,000 feet, but the amount is somewhat greater to the south. In the vicinity of Rapid Creek the Piney formation is composed of alternating layers of white sandstone, ironstone concretions, light-yellowish clay, and thin beds of leaf-bearing shales with thin seams of coal; dark-brown clay also occurs in places. Toward the base of the series the sandy layers become harder, outcropping in massive ledges, and at the base is a layer of light greenish-gray, compact sandstone lying on the Parkman sandstone. The strata dip to the northeast at an angle of about 30° and the thickness of the formation here is over 3,000 feet.

KINGSBURY CONGLOMERATE.

The conglomerate deposits overlying the Piney formation appear on the south side of Beaver Creek, developing either out of the lower portion of the top beds of the Piney formation or of the lower beds of the De Smet formation. They thicken rapidly, and from Johnson Creek to Buffalo have a thickness of several thousand feet. Toward Crazy Woman Creek they rapidly thin and disappear or give place to fine sediments. The conglomerate attains its greatest prominence in the high ridge lying east of North Fork of Rock Creek, where for several miles there are conspicuous ledges over a hundred feet high. The materials are pebbles and bowlders, mostly of Carboniferous limestones and darker colored chert and the very distinctive flat-pebble conglomerate of the Deadwood formation of the mountains west—ingredients which indicate uplift and deep degradation. Granite pebbles occur in small numbers to the north, but they are more abundant in the exposures along Piney Creek, and none were observed near Clear Creek and southward. Many of the pebbles are in a disintegrating condition and some show evidences of more or less shearing. The conglomerate occurs mostly in layers 6 to 12 feet thick, interbedded with dark-greenish to light-yellow clays. Layers of

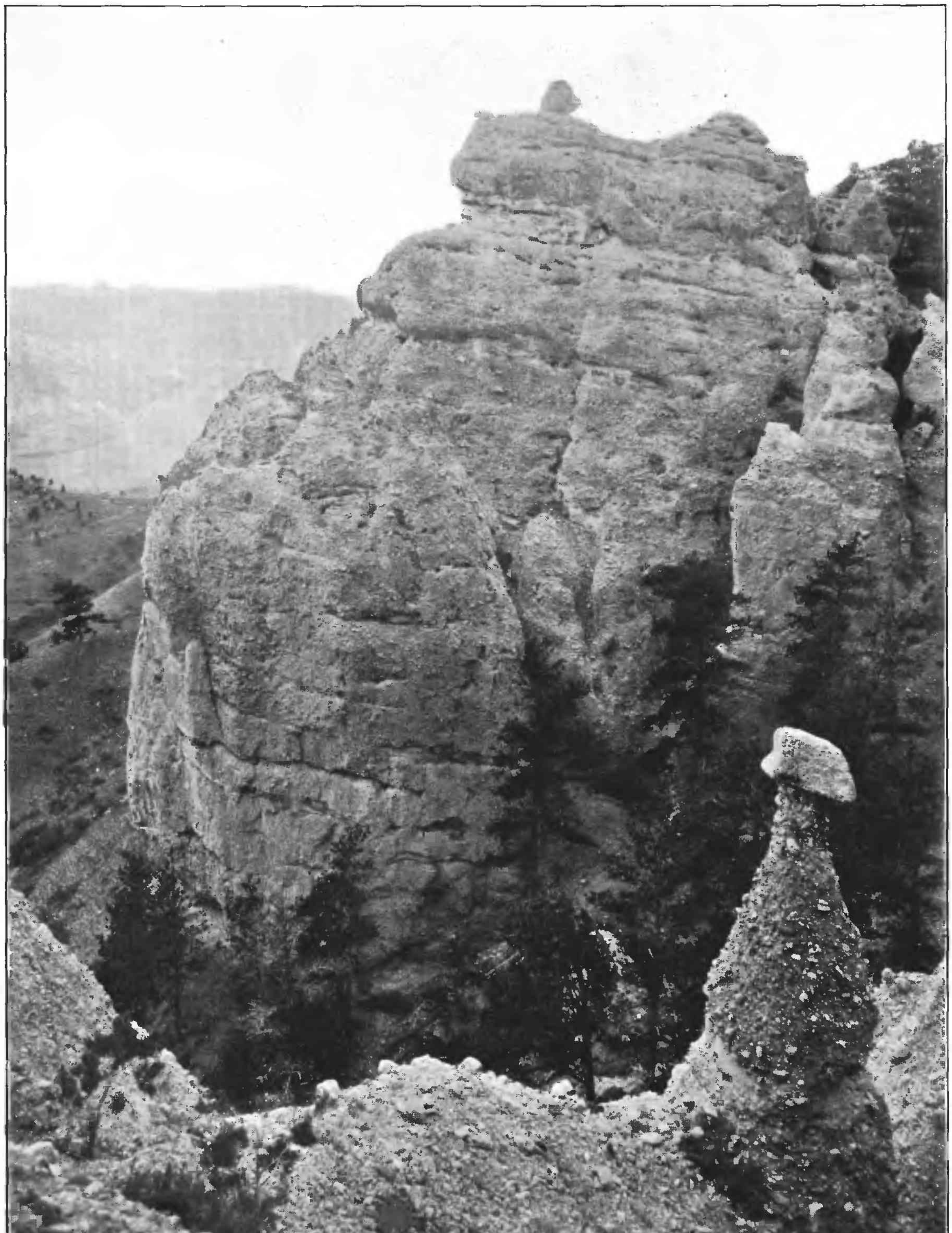


A. LIMESTONE BRECCIA OF KINGSBURY CONGLOMERATE ON MADISON LIMESTONE.

At great fault and overlap south of Bighorn, Wyo. Looking north over lowlands of De Smet and underlying formations

B. KINGSBURY CONGLOMERATE ABUTTING AGAINST MADISON LIMESTONE.

North Branch of North Piney Creek, east side of Bighorn Mountains, northwest of Buffalo, Wyo.; shows irregular bodies of soft sandstone included in the formation.



KINGSBURY CONGLOMERATE.

East slope of Bighorn Mountains, northwest of Buffalo, Wyo., north side of Rock Creek Valley. Looking west to mountains.

a wide range that they do not indicate the precise age of the beds. The name Kingsbury, here used for the first time, is from Kingsbury Ridge southwest of Buffalo.

DE SMET FORMATION.

Coal measures.—These beds, formerly referred to the Laramie formation, lie above the Piney formation and Kingsbury conglomerate, with a thickness of over 5,000 feet. They dip eastward under a wide area at angles of from 3° to 8°. The dips are 10° to 30° near the conglomerate, but decrease rapidly to the east. The inclination of the strata is to the northeast about Buffalo and northward to the east near Crazy Woman Creek. The beds consist of alternating shales and sandstones, the former mostly carbonaceous and the latter soft and massive. The stratigraphy is variable, and no regular succession of beds could be established. The coal occurs in local beds at various horizons, and, while most of the deposits appear to be of limited extent, a large amount of coal is available. The most extensive exploration of the coal measures in this area is at the Dietz mine, near the mouth of Big Goose Creek. The section given in fig. 1 is found in the drifts and shafts.

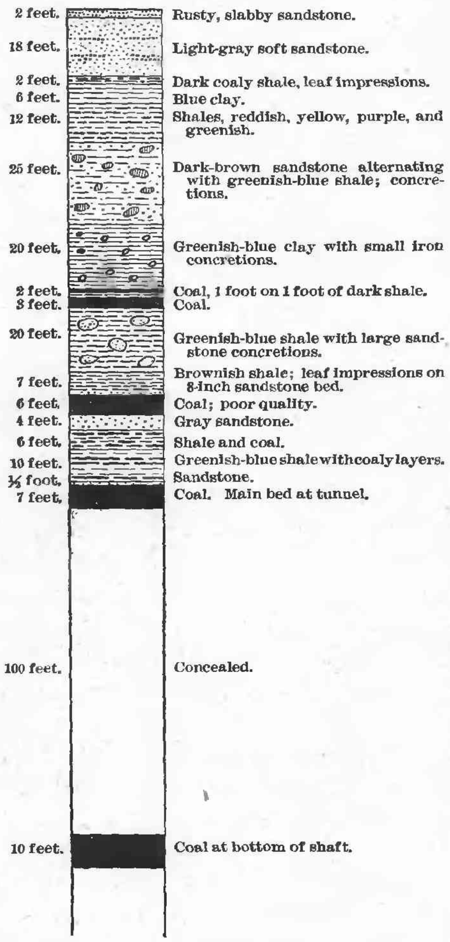


FIG. 1.—Section of coal measures at Dietz coal mine, Wyoming.

On Owl Creek and the divide to the north the coal measures contain a coal deposit 18 feet thick, which is extensively mined 2 miles northeast of Beckton. The 3 feet at the top are a mixture of shale and coal. The coal outcrops across the divide toward Soldier Creek, but it appears to thin out rapidly in that direction, being only 6 feet thick in an abandoned mine on the north slope. To the south the coal outcrop encircles the hill lying between the mouths of Owl and Big Goose creeks and is opened extensively at the Big Goose coal mine, on the east side of the hill. The bed here is 14 feet thick. On the east side of Beaver Valley, 2½ miles farther southeast, this bed has a thickness of 21 feet without parting. This is at Nelson Brothers' coal mine, 2 miles above the mouth of Beaver Creek, where the same bed of coal is worked as at the Big Goose and Owl Creek mines. The strike of the beds is northwest-southeast in this region and the dip about 4°. The coal thins in every direction from the Nelson mine. The overlying beds exposed at intervals down Goose Creek are soft sandstones and shales with coaly layers. A partial section is as follows:

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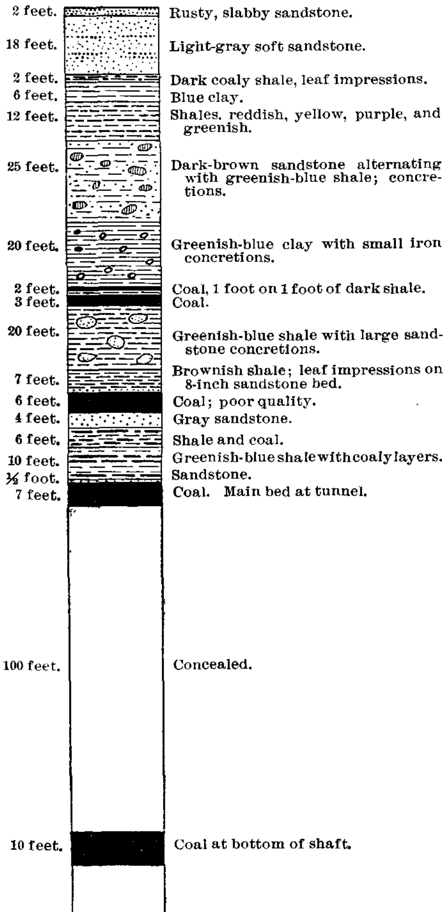

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Section of coal measures on Big Goose Creek, in northwest corner of T. 55, R. 84, Wyoming.

	Feet.
Yellow clay	10
Leaf-bearing shale	7
Coal with thin shaly partings	3
Dark leaf-bearing shale	15
Coal with thin shaly partings	3
Black coaly shale and blue clay	4
Reddish sand	4
Yellowish sandy clay with ironstone concretions to level of creek	30

At a coal prospect 3 miles northeast of Wolf is a layer of coal 1 foot thick. It is overlain by dark-reddish shales containing plant remains and lies on blue clay.

At one time coal was worked on North Dry Creek 2 miles south of Tongue River, but, as the opening has caved in, the beds could not be measured. In the bed of the creek near by 4 feet of coal are exposed, overlain by dark-brown leaf-bearing shales. The bottom of the coal bed is below the creek and the thickness could not be ascertained. Apparently it is the bed which was worked in the mine. The coal is of good quality and easily mined.

Three miles east of Ranchester a draw on the south side of Tongue River exposes the following beds, having a very low dip:

Section of coal measures 3 miles east of Ranchester, Wyo.

	Feet.
Rust-colored shale	2
Gray sandy shale	5
Coaly shale, plants	6
Red and gray shale	6
Sandstone, rust colored	2
Coal	1
Blue shale	1
Coal	1
Gray shale	10
Talus to river	9

These beds appear again north of the river along the divide between Sixmile and Earley creeks. On the summit of this ridge several thin layers of coal are exposed, varying in thickness from 1 to 4 inches, separated by 20 to 25 feet of bluish-green clay with ironstone concretions. On the north side of Earley Creek, 3 miles northeast of Ranchester, the next higher beds are exposed, as follows:

Section of coal measures on Earley Creek 3 miles northeast of Ranchester, Wyo.

	Feet.
Clinker bed	10
Pale greenish-yellow clay	50
Red sandstone	4
Bluish-green clay	15
Gray sandstone	6
Light-yellow sandy clay	25
Bluish clay	15
Coaly shale, leaf impressions	8
Coal	4
Dark-gray shale	1
Coal	10
Bluish-green clay and shale	40
Coaly shale with thin coal streaks	20
Talus and red clinker-like rock	10
Light-brown clay with ironstone	20

Section of coal measures on Earley Creek 3 miles northeast of Ranchester, Wyo.—Continued.

	Feet.
Shale with plant fragments	2
Coal	⅓
Coaly shale	2½
Coal	1
Coaly shale	2
Coal	1
Blue-green clay	6
Coal	1
Dark clay and shale	

The upper beds of this section cross Tongue River just east of the mouth of Earley Creek, where the coal is mined in small amount. The thickness of the bed varies from 5 to 6½ feet. This coal is also mined to some extent for local use on the ridge northwest. A section of the De Smet beds in the ridges east of Parkman is given in fig. 2.

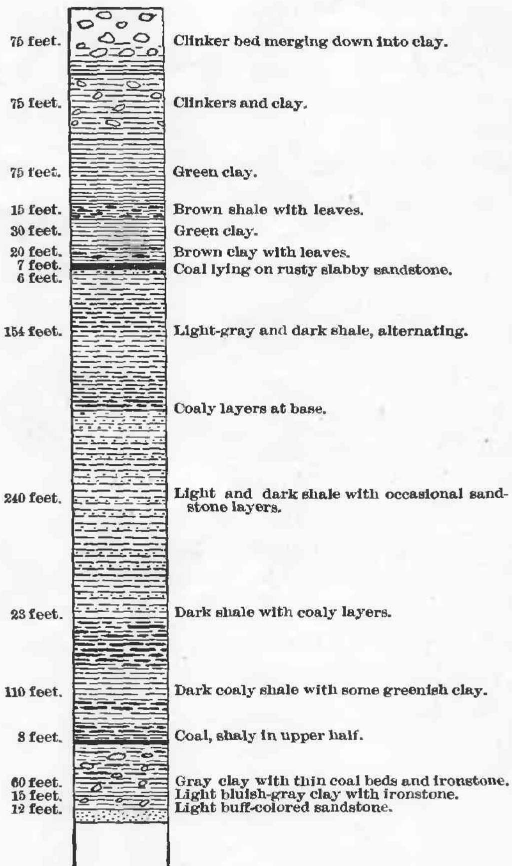


FIG. 2.—Section of a portion of the De Smet formation east of Parkman, Wyo.

Many ironstone concretions occur in the clays of the coal measures of the De Smet formation, and there are also numerous rust-colored sandstone concretions. Both of these weather out on the slopes and often accumulate in deposits of considerable thickness as the clay washes away.

In the Lake De Smet region and southward there are four principal coal horizons lying near together a few hundred feet above the base of the formation. In the region northeast and east of Buffalo part of the coal has burned out near the surface and over wide areas the heat has baked the adjoining shales into red clinkers. At some localities the coal is still burning, notably at an abandoned coal mine near the southeast corner of Lake De Smet.

The lowest member of the coal measures in this region is the usual series of sandstones lying on the conglomerate and merging upward into coaly shale, which extends north and south for some distance in the region north and west of Buffalo. On the east side of Rock Creek, in the northeast corner of T. 51, R. 83, this coaly shale is about 6 feet thick and contains three or four streaks of poor coal. The principal coal deposits of the Buffalo region occur considerably higher in the formation and one series outcrops along a zone extending from the southeast corner of Lake De Smet to the mouth of Rock Creek and thence east of Buffalo. Near Lake De Smet the old mines have caved in, but they appear to have worked about 4 or 5 feet of coal. It is overlain by a bed of clinkers. Near the mouth of Rock Creek, at the Bodan coal mine, a tunnel has been run in on a 12-foot coal bed of good quality. The section at this place is as follows:

Section at Bodan coal mine, near Buffalo, Wyo.

	Feet.
Clinkers	6
Yellow sandy clay with 6 feet of concretionary sandstone at base	30
Reddish-yellow clay	4
Dark shale with plants	2
Coal	12
Light-gray shale	2

The coal appears to be in a lens-shaped deposit and thins considerably to the north and south. A short distance north an 8-inch coal bed is seen underlying the clinker bed. A mile east of the Bodan mine and at a somewhat higher horizon is the old Foot mine, in which an 8-foot bed has been worked. This is overlain by a succession of 20 feet of light sandy clay, 20 feet of dark shale with thin coaly streaks, and 15 feet of yellow sandy clay. This coal deposit is on fire and has been burning for several years. The section in fig.14 (p. 112), at Monker & Mather's mine, 1 mile east of Buffalo, shows the principal succession in that region. The lower 7-foot bed is probably the lowest bed of importance in the formation. The upper 7-foot bed reaches the surface near the mouth of Rock Creek and has been worked in the Bodan, Foot, and Lake De Smet mines. The next bed lies some distance above and is worked at the Mitchell mine, 2½ miles east of Buffalo, where it occurs a short distance below a thick clinker bed. It is 6 to 8 feet thick.

The highest coals in this region are found in isolated areas in the buttes and plateaus of the clinker region 10 miles northeast of Buffalo. The beds apparently are remnants of deposits which are burned out elsewhere. They are included in strata free from clinker and in part capped by gray sandstone and clay, which caps the upper clinker bed in some other places in the region. A number of such occurrences were observed in and adjoining the northwest corner of T. 51, R. 80.

In its southern extension the De Smet formation contains coal, but no large deposits appear near the foot of the mountains. There is a uniform succession of sandstones and shales with coaly layers at intervals. The stratigraphy is less marked than in the region to the north and the only noticeable feature is the occurrence of clinker for a short distance in two lines of small buttes south and southwest of Long's ranch. Coal 6 feet thick is mined 2 miles southwest of Long's ranch, but it s not of very good quality.

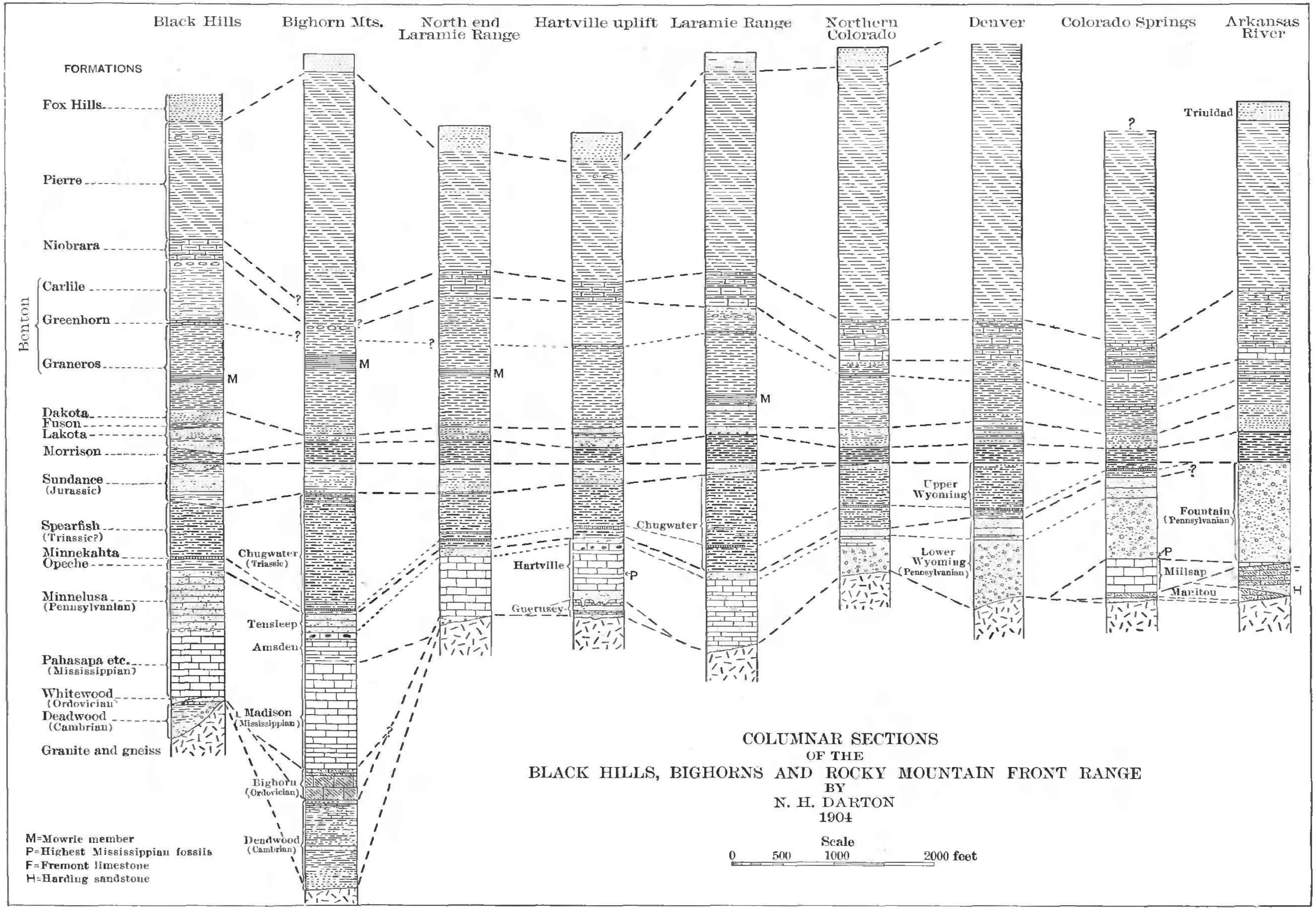
Clinker beds.—The upper strata of the De Smet formation consist largely of clinker beds, which cap many slopes and divides. They present a great variety of color, mainly due to different degrees of oxidation of the materials. Brick-red predominates and purplish and maroon tints are noticeable. The partly burned clays are of pale-red, canary-yellow, and maroon tints. Much of the rock resembles a slag and shows that it has been completely fused by the heat of the burning coal.

In some portions of the region coal is still burning; the combustion is deep in the bank in most cases, but is evidenced by the smoke and steam and the heat of the surface.

North of Sheridan the upper clinker beds occur in a series consisting of a thick deposit of light-yellow sandy clay, overlain by layers of massive red sandstone, above which is a considerable thickness of greenish-yellow clay capped by the clinker bed, in all about 100 feet. The clinker is burned to various bright colors—red, green, light and dark yellow, red, red-brown, pink, and gray. The sandstones outcrop frequently, but often are too soft to be prominent.

The clinker beds are prominent features in a wide area of the formation east of Buffalo. They cap extensive plateaus and buttes in all the region about Lake De Smet and extend along both sides of Clear Creek Valley. Owing to the hardness of the material the topography is rugged and the bright-red color of the rock renders it very noticeable. The thickness of the beds varies from a few inches to 20 feet or more. Two principal horizons occur, the upper one in a series varying in thickness from 150 to 200 feet, consisting of buff sandy clay, and sandstones capped by a deep-red clinker deposit. Usually the sandstone is soft, but in places it thickens and becomes very hard, forming a massive gray ledge weathering into small castellated forms which are conspicuous along Boxelder Valley northeast of Lake De Smet. The upper clinker bed varies in thickness from 10 to 60 feet, merging from a highly burned clinker at the top to an unaltered clay at the bottom. There is evidence in some places that the upper clinker bed was originally a mixture of coal and clay and that the coal has burned out. The lower clinker bed occurs in a series of buff to light-brown and green clays, light-colored sandy clay, sands, sandstones, and a few layers of leaf-bearing shale and coal. Between the two clinker beds there probably was originally much coal, but it is burned out in most localities. At a point in the southwest corner of sec. 36, T. 52, R. 81, some of the coal is exposed. The bed appears to be lens-shaped, 2 to 6 feet thick, and overlain by a series consisting of 2 feet of clay burned to clinker at some points, 10 to 12 feet of impure coal and coaly shale, 4 to 6 feet of coaly shale, and 10 to 15 feet of clay capping the butte. Above the two upper clinker series is a massive sandstone of dull-gray color, 10 to 15 feet thick, which caps the higher portions of the plateau divides on either side of Clear Creek Valley. In places this sandstone is overlain by clay with local masses of clinker which rise in low mounds at a few points on the divides in Tps. 51 and 52, Rs. 80 and 81, and 2 miles east of the north end of Lake De Smet. The largest area is in the southwest corner of T. 52, R. 80, where the upper clinker bed is overlain by dull-gray, massive sandstone, 6 to 12 feet thick, containing unios, and this in turn is overlain by clay with impure coaly beds, in places partly converted into clinker. These are the highest beds in the region.

Fragmentary fossil leaves from beds underlying the lower clinker bed 2 miles north of Buffalo appear to comprise *Sequoia langsdorfii?* (Brgt.) Heer and *Musophyllum complicatum?* Lesq., according to determinations by Mr. F. H. Knowlton, who states that they indicate early Tertiary age (Eocene). The fossils found in the upper gray sandstones overlying the upper clinker bed 3 miles northeast of bench mark 4279 are casts of a unio resembling *U. cryptorhychis* White, a form which may be Laramie or older.



COLUMNAR SECTIONS OF THE BLACK HILLS, BIGHORNS, AND ROCKY MOUNTAIN FRONT RANGE.

Section of upper De Smet beds on east side of Clear Creek, 10 miles northeast of Buffalo, Wyo.

	Feet.
Clay with coaly streaks	20
Sandstone	10
Upper clinker beds	20
Light-buff sandy clay	10
Slabby gray sandstone	20
Light reddish-brown clay	30
Sandy and buff clay with sandstone layers	25
Lower clinker beds merging into coaly shale	40
Rust-red sandstone	4
Buff to light brown clay	60
Impure coal	3
Buff clay	40
Buff sandy clay	10
Sand and sandstone	40
Coal	12
Sandstone with large concretions to Clear Creek	40

The name De Smet here proposed for this formation is from Lake De Smet, a locality in which it is typically exposed. Owing to lack of paleontologic data it is not correlated with other formations, and while it may be in part Laramie it may include higher beds.

TERTIARY SYSTEM.

At various localities along the middle slopes of the Bighorn Mountains there are deposits of sands, volcanic ash, gravel, and bowlders which are older than the glacial drift of the early Quaternary and therefore are provisionally classed in the Tertiary system. Some of the deposits are older than others, but it has not been found possible to classify them satisfactorily. One of the most remarkable areas caps a portion of the main divide between the heads of North Fork of Powder River and Canyon Creek, at an altitude from 8,700 to 9,100 feet. Other notable areas lie north, south, and southeast of Hazelton, on the east flank of the range, where they constitute the prominent Bald, North, and Moncrief ridges; near the heads of Canyon and Lee creeks; east of Soldier Creek, and on the high ridge west of the lower portion of North Fork of Paintrock Creek. Smaller areas occur west and north of Black Butte, north of the mouth of Middle Fork of Paintrock Creek, on the divide north of Tongue River, along Clear Creek, and on slopes of the limestone front range northwest of Buffalo. The deposits on the slopes east of Canyon Creek are especially well exposed at a point shown in Pl. XXII. A section at this locality, made by Mr. Bastin, is as follows:

Section 1 mile south of bench mark 9069, east of Canyon Creek, Wyoming.

	Feet
Sandy clay soil	6
Gravel, of crystalline rock, with lenses of volcanic ash near the base, and with occasional bowlders up to 2 feet in diameter	60
Volcanic ash, arkose, fragments of igneous rock, etc., indistinctly stratified	73
Conglomerate, cemented by lime carbonate; bowlders up to 4 feet in diameter and generally well rounded.	22

The amount of volcanic ash in this section is large, and it appears to have been laid down by water, though some of the finer portions may be wind blown. The nearest eruptions from which it could have been derived so far as known are in the great volcanic area west of the Bighorn Basin, where there were extensive eruptions in Tertiary time. Volcanic-ash deposits are generally characteristic of the Tertiary rocks in the Black Hills region and eastward, so that, from their position and the conditions of occurrence, the above-described deposit is provisionally referred to the Tertiary, but there is no evidence at present for correlating it with any of the divisions of that system. Some features of this deposit suggest that it is separable into two members, the upper one forming the surface of the extensive prairie which is the main divide in this vicinity. A view of this prairie is shown in Pl. XXIII. The conglomerate with lime matrix appears at intervals southward from the exposure above described and forms low bluffs near the top of the plateau east of Canyon Creek. The areas on the two divides east of Soldier Creek are 3 and 5 miles west of West Tensleep Lake and both are at an altitude of about 9,100 feet. The conglomerate of lime matrix and volcanic ash appears again at these localities, together with a large number of decayed bowlders. The extensive areas capping the high ridge west of the mouth of Middle Fork of Paintrock Creek slope from altitudes of 8,200 feet at the south, 8,300 feet at the west, and 8,950 feet at the north. The thickness here is 50 feet at some points, and the greater part of the material consists of bowlders and granite débris, mostly rotted. Two small outliers occur, one to the west at an altitude of 8,500 feet, and the other to the east on the ridge between North and Middle forks, capping Deadwood beds at an altitude of 9,000 feet. A small area caps a knoll at an altitude of 8,300 feet a mile west of Black Butte. It consists mostly of large bowlders and sand. Other similar deposits cap the small ridges lying between Medicinelodge Creek and Shell Creek along the Deadwood outcrop. The altitudes are from 8,900 to 9,100 feet.

A deposit similar to those at the head of Powder River is exposed on North Fork of Crazy Woman Creek, near the main road 6 miles northeast of Hazelton. It consists partly of light-colored sandy loam with hard concretions and partly of a conglomerate of bowlders with carbonate of lime cement. It is similar in appearance to some of the Oligocene deposits in the Black Hills, so it is provisionally correlated with them. The deposit appears to occupy a depression in granite and to be of limited extent, but possibly it extends southeastward under the cap of the high-terrace gravels extending to the head of Billy Creek. The exposure is in a bank 30 feet high. Although careful search was made for bones and other fossils, none were found.

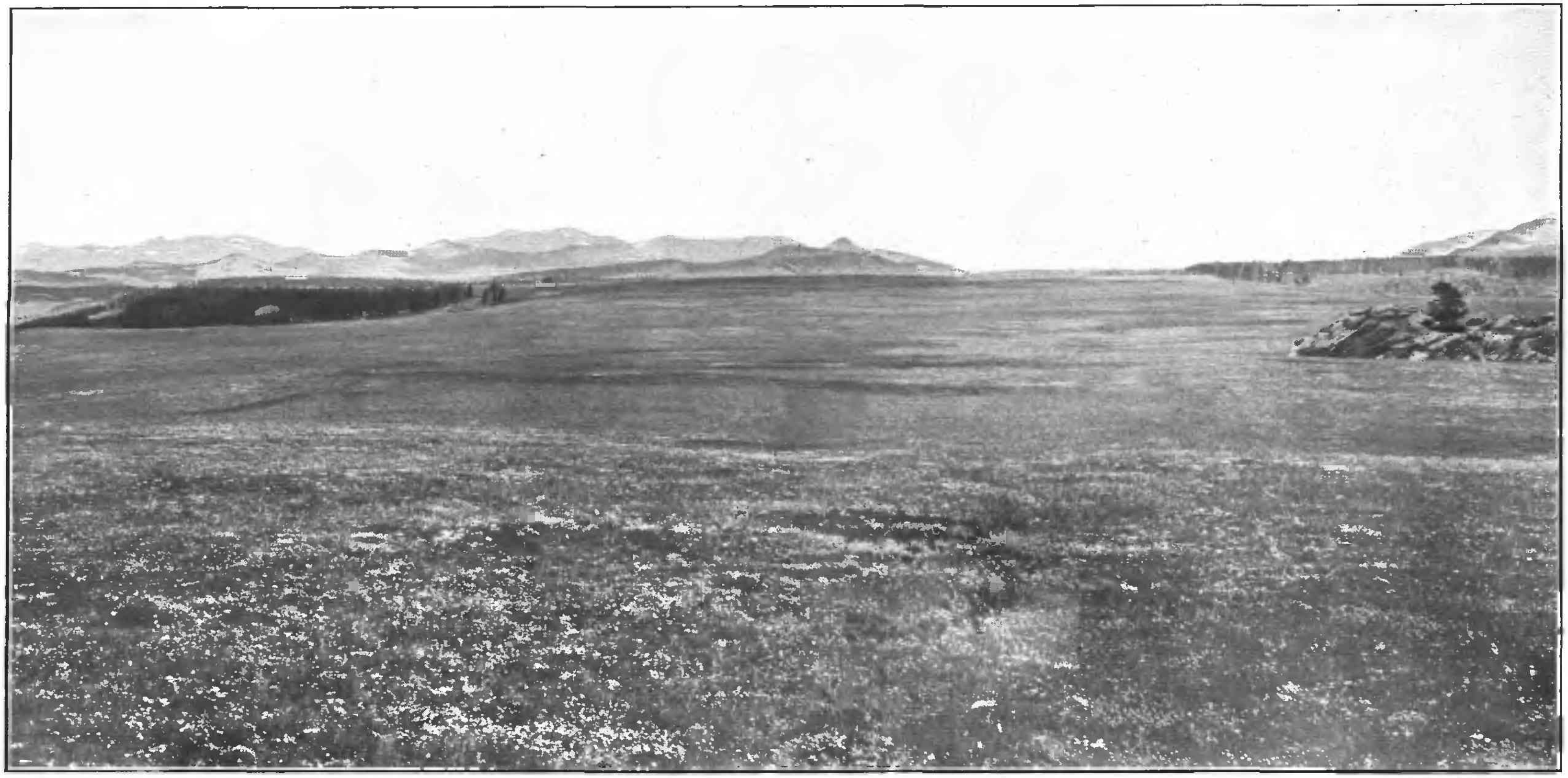
Among the most conspicuous features on the east slope of the mountains are the two high bowlder ridges at the mouth of Clear Creek Canyon, west of Buffalo, and the similar ridge 6 miles south of Bighorn. The southern one of the pair west of Buffalo is known as Bald Ridge and the northern one as North Ridge. Their altitudes are 6,900 and 6,800 feet, respectively. Their 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 bowlders 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 bowlders of medium and small size are completely rotted. Apparently there are no limestones or sandstones in the deposits, notwithstanding the proximity of ledges of

A. TERTIARY DEPOSITS CAPPING MAIN DIVIDE OF BIGHORN MOUNTAINS.

Between heads of North Powder River and Canyon Creek; looking south along east side of Canyon Creek. Fine-grained beds of sand and volcanic ash below, capped by bowlders and sand, possibly of Quaternary age.

B. NEAR VIEW OF TERRACE DEPOSIT ON TERTIARY SANDS ON BIGHORN DIVIDE.

East side of Canyon Creek; looking north. Shows bowlders and sand.



HIGH PLAIN OF SUPPOSED TERTIARY DEPOSITS ON SUMMIT OF DIVIDE ON BIGHORN MOUNTAINS.

Between head of North Fork of Powder River and Canyon Creek, 10 miles west of Hazelton, Wyo.; looking north-northeast toward the central range.

these rocks to the west. The thickness was not ascertained satisfactorily, but it amounts to several hundred feet, as near the mountain slope the deposit appears not to be cut through by Clear Creek, though farther east the underlying sandstones appear. The precise limits can not be determined, because the bowlders have slid down the slopes. A distant view of these ridges is given in Pl. XXIV. To the south a small outlier appears on the summit of Kingsbury Ridge, southwest of Cross H ranch, at an altitude of 6,100 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 Creek west of Kearney, being clearly remnants of a deposit which at one time extended all along the front range.

Moncrief Ridge, south of Bighorn, 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 shallow 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 bowlders, 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 Pl. XXV. Many of the bowlders 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.

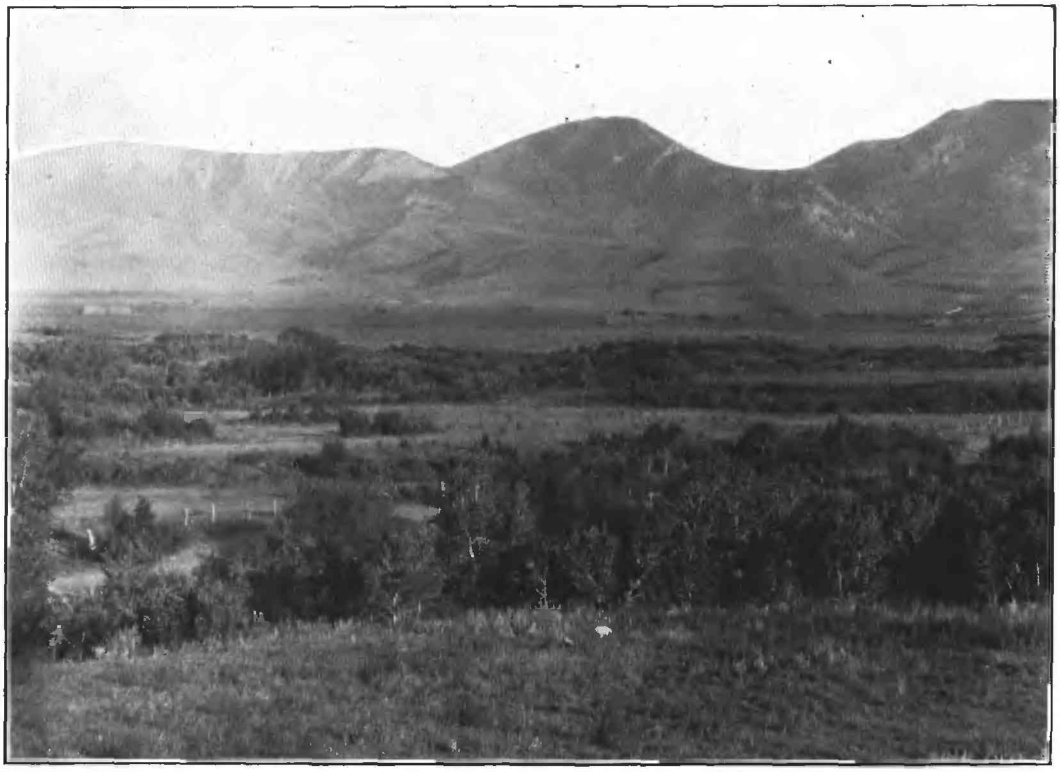
In Clear Creek Valley, west of the limestone ridge and lying mostly on the north side of the creek, is a wide, high terrace floored by gravel and bowlder deposits which apparently were once continuous with those of Bald and North ridges. They are thin, however, and are deeply trenched by the present creek canyon. To the west they extend up the valley to an altitude of about 7,100 feet, or nearly to the outer margin of the moraines of the earlier Glacial epoch. Five miles south, on the divides adjoining Little Sour Dough Creek, a deposit of gravel and small bowlders covers an area of considerable extent, at altitudes mostly from 7,700 to 8,100 feet. It floors a level area or series of parks among the granite slopes. A similar but much more extensive area of this intermontane gravel plain extends east and northeast from Hazelton to North Fork of Crazy Woman Creek, and some small, detached areas occur on the north side of that valley. The wide, rolling plains and open parks are a conspicuous feature. The altitudes mostly range from about 7,800 to 8,300 feet, there being a general downward slope to the east. Apparently the original area of the deposit was somewhat greater than at present, for Big Poison Creek and North Fork evidently have removed portions of it. Other similar plains, mostly covered by gravel, occur southwest and southeast of Hazelton on Beaver and Doyle creeks and North Fork of Powder River, at altitudes from 8,100 to 7,500 feet. These deposits appear to have been the products of an earlier period of topographic development and mark the course of streams which passed through gaps in the limestone front ridge at a much higher level than the present drainage. Remnants of these gaps are strongly suggested by the configuration of the slopes above the canyons of Clear, Billy, and some of the other creeks.

The only evidences of Tertiary deposits found in the northern portion of the Bighorn Mountains are two narrow areas of peculiar sands capping low divides on the north side of Tongue River Valley. One, which is traversed by the main Tongue River road, lies 1 mile west of the mouth of Fool Creek at an altitude of 7,800 feet. The other occupies an area of a few square rods on the divide at the head of East Fork of Dry Creek at an altitude of 9,000 feet. Both lie on limestones. The material of these deposits is a white, buff, and flesh-colored loam or sandy clay of somewhat chalky texture, resembling portions of the White River formation and including some streaks of gravel and limestone fragments. The thickness was not determined, but it is 30 feet at least, and possibly much more. No fossils were observed, and the only evidence of Tertiary age is the peculiar aspect of the deposit and its occurrence on the old divides, a characteristic of the Oligocene sediments in other mountainous regions of the Northwest. Possibly there are deposits of this kind in other divides, but they were carefully sought for along every line we traveled and were not found. There is some evidence of the occurrence of a similar deposit in the low divide just south of Shell Creek, near the southeast corner of Bald Mountain quadrangle, but it is not well exposed and appears to be wash from a former glacier.

In the southern portion of the Bighorn Mountains several small areas of Tertiary deposits remain in some of the divides. The largest area observed is on Pass Creek, near the center of T. 48, R. 85. Another exposure appears in the low saddle a mile northeast of Cheever's ranch. The materials consist of light-colored loams, which weather into miniature badlands.

The age of the high-level bowlder deposits is not ascertained. The deep decomposition of the bowlders 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 bowlders show no signs of glaciation, but, owing to the decay, striæ 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. Bowlders 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.

At the southern end of the Bighorn Mountains there is an extensive overlap of the "Bridger" formation, which is of Tertiary age. It extends to a moderate height up the slopes of the ridges in the vicinity of Badwater and Bridger creeks and occupies a wide area on the northern side of the saddle separating the Bighorn and Bridger ranges. In this saddle the deposits are over 800 feet thick, and consist of sands, clays, and sandstones ranging in altitude from 6,200 to slightly over 7,000 feet. Near the base there are several members of hard, massive sandstones; next above are light-colored sandy clays, mostly of yellowish color; and in the upper part are brown sandstones in deposits 15 to 20 feet thick in light-gray clays, sometimes containing considerable chert. Smaller deposits also extend up some of the valleys, especially along Sioux Creek and near the headwaters of No Wood. The formation also skirts the southern slope of the Bridger Range, overlapping the granites and schists in ranges 91, 92, and 93. No special study was made of these Tertiary deposits, nor is it even certain that they consist entirely of the "Bridger" formation.



A. MONCRIEF RIDGE; HIGH BOWLDER TERRACE ABUTTING AGAINST EAST SLOPE OF BIGHORN MOUNTAINS.

Six miles southeast of Bighorn, Wyo.; looking across valley of Little Goose Creek. Granite to right, Bighorn and Madison limestone ridge to right of middle, bowlder terrace to left.

B. HIGH BOWLDER TERRACES ON EITHER SIDE OF CLEAR CREEK.

East slope of Bighorn Mountains, west of Buffalo, Wyo. View from Johnson Creek; looking south to terraces in distant middle-ground. Front ridge of Bighorn and Madison limestone to right, against which are faulted the De Smet formation in the middle-ground.

NEAR VIEW OF HIGH-LEVEL BOWLDER DEPOSIT AT NORTHWEST END OF MONCRIEF RIDGE.

Six miles southeast of Bighorn, Wyo.; looking east. Bowlders are mainly granite, mostly rotted and in matrix of sand.

QUATERNARY SYSTEM.

GLACIAL GEOLOGY.[a]

By R. D. SALISBURY.

Several small glaciers remaining in the higher portions of the Bighorn Mountains are diminutive remnants of much more extensive bodies of ice which formerly occupied the principal valleys of the highlands. In this respect the history of the Bighorn Mountains is similar to the history of other high ranges similarly situated in the western part of the United States. The glacial history of these mountains is complex, and the great glaciers which have left the most distinct records of themselves were the successors of earlier ones, the marks of which have been partly effaced by weathering and erosion. There is evidence that the Bighorn Mountains were occupied by glaciers during two widely separated glacial epochs, and there is some suggestion that there may have been glaciers at a still earlier time. Because of the unequivocal nature of the phenomena connected with the last epoch of glaciation and the obscure nature of the phenomena connected with earlier glaciation, it is best not to follow chronological order, but to consider first the record of the last glacial epoch. The distribution of the principal features is shown in Pl. XXVI.

THE LAST GLACIAL EPOCH.

PROOFS OF GLACIATION.

The phenomena which point with certainty to recent glaciation in the Bighorn Mountains are: (1) The great body of drift which encumbers many of the valleys and which has both the disposition and the constitution of true glacial drift; (2) the shapes of the valleys in which the drift lies; (3) the smoothed and striated surface of the rock of the sides and bottoms of the valleys where the drift occurs; (4) the peculiarities of drainage in these valleys, especially the numerous lakes and the narrow gorges of the streams where they break through the greater aggregations of drift. These distinctive marks are characteristic of all recently glaciated mountain valleys.

EXTENT OF GLACIATION.

By means of the above criteria it is known that the principal valleys of the Bighorn Mountains within an area about 40 miles long by 27 miles wide were recently glaciated. Within this area, however, less than one-third of the surface (about 300 square miles) was covered by moving ice. The associated snow fields, which have left no very definite record of their extent, may have covered considerable additional area. Indeed, at the time of maximum glaciation it is probable that snow and ice were essentially continuous from the northernmost limit of the ice in the valley of South Fork of Tongue River, latitude 40° 41′, to its southernmost limit in the valley of Tensleep Creek, latitude 40° 06′. The map (Pl. XXVIII) shows the extent and principal relations of the various ice sheets. The continuity of the ice was probably interrupted (1) by a few peaks and narrow divides whose slopes were too steep to permit the lodgment of snow; and (2) by numerous precipitous slopes along the

[a] This account of the glacial geology of the Bighorn Mountains is based on the work of assistants operating under the direction of R. D. Salisbury. Most of the investigation was conducted by Eliot Blackwelder, who prepared a report on the drift of the east side of the range, and Mr. Edson S. Bastin, who studied the drift of the west side. Mr. Blackwelder was assisted by Messrs. W. H. Emmons and F. W. DeWolf, and Mr. Bastin by Messrs. A. D. Hole, E. D. Leffingwell, S. R. Capps, W. W. Magee, and A. R. Taylor. Professor Salisbury visited a few of the valleys which were glaciated and has seen the older drift at a few points, but the facts stated were gathered chiefly by Messrs. Blackwelder and Bastin.

sides of those valleys which were occupied, but not filled, by the ice. The westernmost point reached by the ice of this epoch was in the valley of Shell Creek (longitude 107° 32′), and the easternmost in the valleys of North and South forks of Clear Creek (longitude 106° 58′). Snow and ice were two or three times as prevalent in the Bighorn Mountains at the time of maximum glaciation in the last glacial epoch as they now are in Switzerland, for though the area covered by snow and ice in the Bighorns was probably no more than half that now occupied by snow and ice in Switzerland, the territory in Switzerland within which such conditions are found is about five times as great as that within which glaciers occurred in the Bighorns. The largest of these glaciers was much more extensive than the largest existing glacier in Switzerland.

From the snow fields which centered about the upper parts of the range glaciers descended all the principal valleys. The number of sources from which they started was little less than 100, but in descending various glaciers united as their valleys came together, so that at the time of maximum glaciation the number of separate glaciers or systems of glaciers, as determined by the number of lower termini, was but 19. Two of these glaciers were simple (not made up of two or more) and very small, but most of them were compound. For example, the ice of Paintrock glacier started from fully 20 sources. Before the ice reached its maximum, therefore, and again after decadence had set in the number of separate glaciers was greater than when the ice was at its maximum. In a few cases, especially on the west, a continuous body of snow and ice divided as it moved, giving rise to several lower termini. This division resulted from the overfilling of certain basins and the spread of the ice through low cols to adjacent valleys.

The map (Pl. XXVIII) shows that the glacial systems were about equally numerous on the east and west sides of the range. It also shows that those on the west side were much larger than those on the east, covering in the aggregate almost twice as great an area, and that those on the east fell short of those on the west in width rather than in length. This difference appears to have been due to two factors—(1) the precipitation was probably heavier on the west side, because of the prevailing westerly winds, and (2) the catchment basins on the west side were wider and shallower than those on the east. It is true that the greater capacity of the basins on the west at the present time is partly the result of the greater glaciation on that side, but it is also true that the greater glaciation was in large part the result of the greater original capacity of the basins. This inequality was due to the general configuration of the range, the western slope of which is less abrupt than the eastern. The existing glaciers are all on the east side, the one which is shown on the west side in the topographic map having disappeared by 1903 (Bastin). The reason for the present distribution appears to lie in the better protection of the cirques on the east from the sun, and perhaps also in the westerly winds, which drift much snow over the crest of the range to lodge on the lee side.

ALTITUDE NECESSARY FOR GLACIERS.

The altitude which was necessary for the generation of glaciers in the Bighorn Mountains during the last glacial epoch seems to have ranged from 9,500 to 11,500 feet, the variation being due to the exposure and to the size of the catchment basin. A southern exposure was less favorable than a northern one, and a small catchment basin less favorable than a large one. As the map shows, the largest glaciers radiated from the highest part of the range; that is, from the vicinity of Cloud Peak.

A

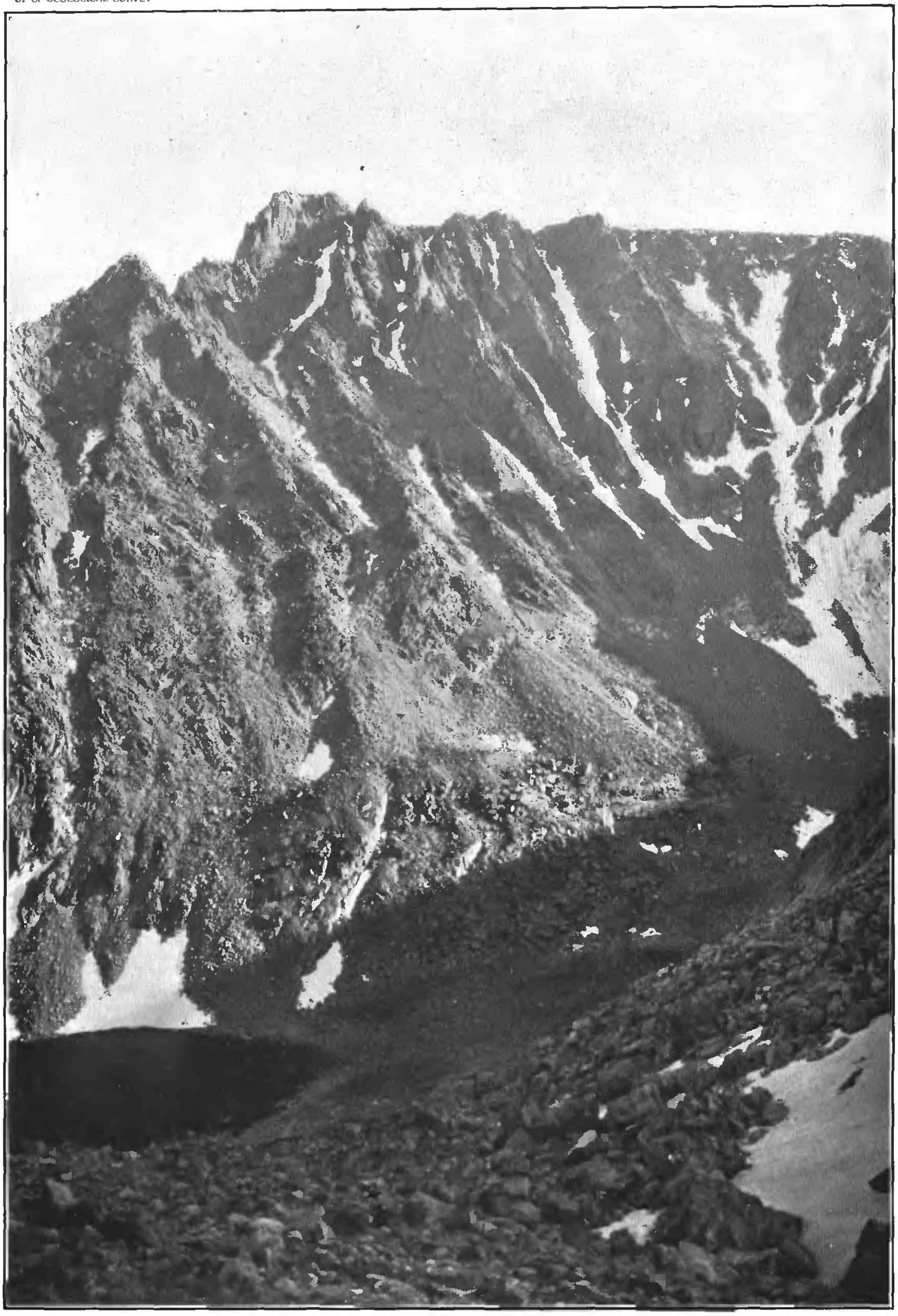
B

WALL AT HEAD OF CIRQUE NO. 7, AT UPPER END OF ONE OF THE TRIBUTARIES OF WEST TENSLEEP CREEK.

A. View from above rim, showing old rounded surface. *B*. View from below rim, showing granite walls nearly 1,000 feet high. Photographs by E. Blackwelder.

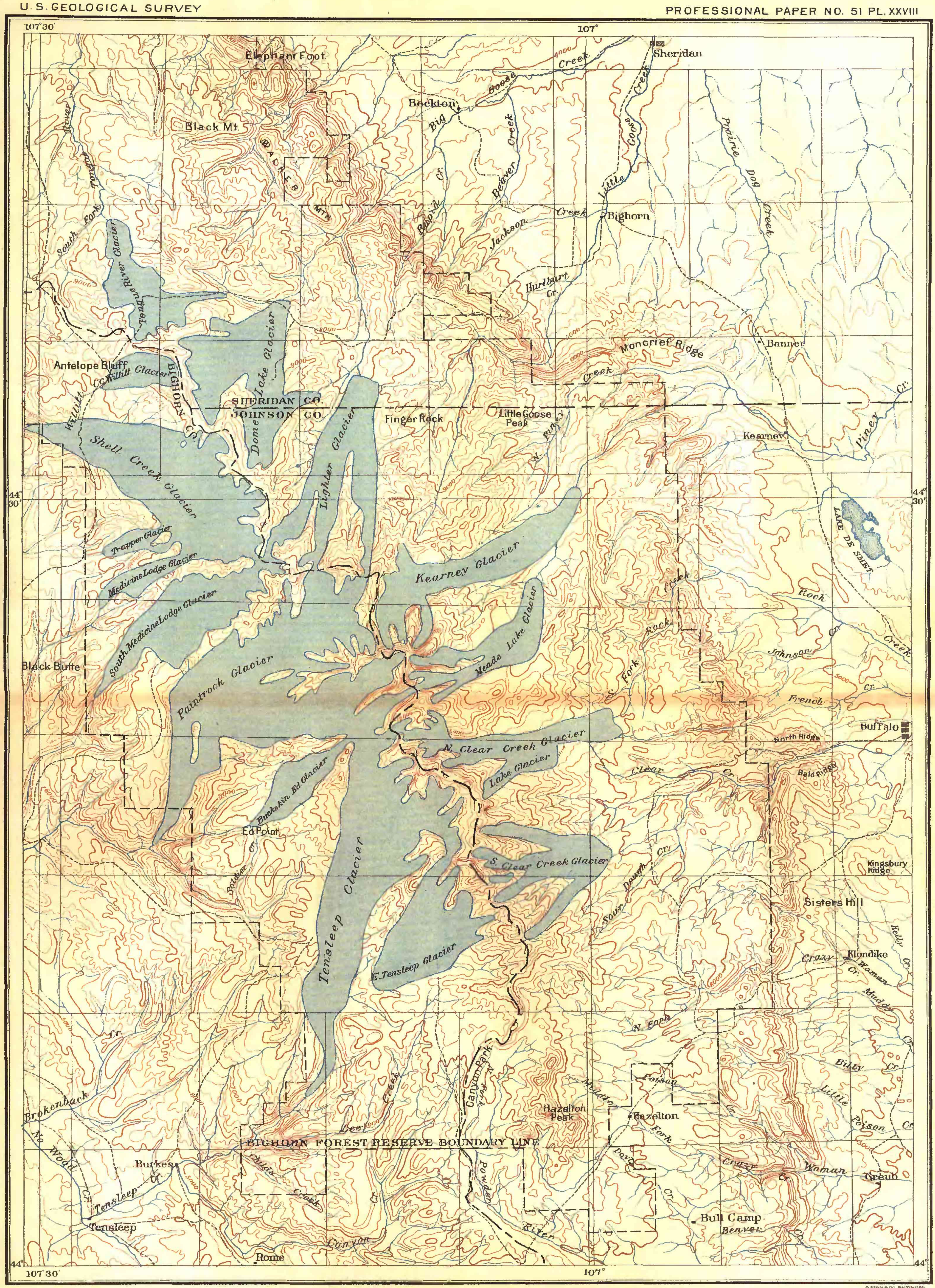
BIGHORN SUMMIT AT CLOUD PEAK AND NORTHWARD.

Typical glacial erosion with small glaciers still present; Cloud Peak to right; great dike of diabase to upper left. Looking eastward from near head of north prong of Middle Fork of Paintrock Creek.



GRANITE RIDGE ON SUMMIT OF BIGHORN MOUNTAINS.

One mile south of Cloud Peak; looking south. Shows powerful erosion by frost on steep cirque wall.



MAP SHOWING FORMER EXTENT OF GLACIERS IN THE BIGHORN MOUNTAINS

BY ELIOT BLACKWELDER

Scale

0 5 10 15 miles

Contour interval 250 feet.

Datum is mean sea level

1905

A. HOEN & CO. BALTIMORE.

LOWER LIMITS OF GLACIERS.

The glaciers descended to very unequal altitudes, depending on the amount of ice, the topography of their beds, etc. Some of the smallest glaciers, such as that at the head of Middle Fork of Clear Creek, descended but little below 10,500 feet, while some of the largest, such as the glaciers of Paintrock and Tensleep creeks, descended to about 6,500 feet.

Many of the valleys of the mountains consist of (1) an upper portion in the mountains proper, often cirque-like, always deep, and in many cases with gradients of 600 to 800 feet per mile; (2) a relatively shallow, open part where they cross the plateau on either side of the higher part of the range; and (3) a second narrow, gorge-like part where they cross the Paleozoic rocks. The smallest glaciers did not descend below the uppermost of these sections, while the longest crossed the plateau and entered the valleys in the Paleozoic formations. None of them reached the plains beyond.

THICKNESS OF THE ICE.

The thickness of the ice in the several glaciers varied greatly. The ice in Paintrock Valley was probably deepest, and at a maximum exceeded 1,500 feet. From this figure the thickness of the ice ranged down to less than 500 feet (maximum) in some of the smallest glaciers, such as that of Willitt Creek. The Dome Lake glacier was relatively thin and weak, as compared with the Lighter glacier on the east and the others to the south. The Shell Creek glacier was broad and feeble and its limits often ill defined. Tongue River glacier was relatively thin, and its movement therefore feeble.

BIGHORN GLACIERS.

The glaciers of the range are listed below, and the table gives approximately their areas and lengths and the altitude of their sources and termini:

Bighorn glaciers of the last Glacial epoch.

Rank.	Name.	Area covered at maximum extension.	Maximum length.	Altitude of source or sources.	Altitude of terminus
		Sq. miles.	*Miles.*	*Feet.*	*Feet.*
1	Paintrock glacier	56.0	16	10,500+	6,200
2	West Tensleep glacier	40.6	17	11,000+	6,500
3	Shell Creek glacier	35.2	14	10,200+	7,500
4	Dome Lake glacier	19.5	8	10,000+	8,000
5	Lighter glacier	18.6	9	10,500+	8,000
6	Kearney Lake glacier	18.4	12	11,500+	7,800
7	East Tensleep glacier	16.0	7	10,500+	8,700
8	South Medicinelodge glacier	15.5	9	10,500+	7,700
9	South Fork Clear Creek glacier	15.0	7	11,000+	8,100
10	North Fork Clear Creek glacier	12.1	10	11,500+	7,900
11	Meade Lake glacier	10.4	8	12,000+	8,800
12	Tongue River glacier	9.6	6	9,800+	8,400
13	Buckskin Ed glacier	7.8	6	11,000+	9,000
14	Willitt glacier	4.0	4	10,200+	8,900
15	North Medicinelodge glacier	3.7	5	10,500+	8,400
16	Lake Creek glacier	2.1	4	11,000+	8,700
17	Trapper Creek glacier	2.1	3	10,500+	8,900
18	Glacier one-half mile north of Pass Creek	.4	1	11,000	10,400
19	Middle Fork Clear Creek glacier	.3	1	11,300	10,400

DISTINCTIVE FEATURES OF GLACIATED VALLEYS.

The distinctive features of glaciated mountain valleys are the following:

1. *Their upper ends are often cirques; that is, they end bluntly above against* high, steep cliffs, and are hemmed in on both sides for a greater or less distance by cliffs of the same sort. The head of South Fork of Clear Creek, just south of the 12,271-foot peak, is an excellent example, and another equally good one lies just across the crest to the west.

2. The valleys which were occupied by large glaciers have rounded bottoms; that is, they are somewhat U-shaped in cross section. This is well shown on the topographic map (Pl. XXVI) as being the case in the valleys of North and South forks of Clear Creek.

3. The cirques, and often the upper parts of the valley below them, are as a rule relatively free from loose material of all sorts, solid rock appearing at the surface in the bottom and on the sides. They were cleaned out by the moving ice.

4. Such bosses of rock as appear in the valleys are often smoothed down to the forms known as roches moutonnées, and their surfaces, as well as the surface of the rock in the valley, are often planed, striated, and grooved.

5. The drift or morainal material is generally most abundant near the lower limit of ice advance, but is often plentiful for some distance above. Where the valleys of these mountains were overspread by vigorous glaciers, drift is meager in the upper halves of the glaciated basins, but abundant in the lower halves. Where the glaciers were feeble, bare rock is less prevalent, even in the upper parts of the basins through which the ice moved.

6. The drift is disposed chiefly in (*a*) broad terminal moraines, which cross the valleys and whose lower side often rises several hundred feet above the valley bottom, and in (*b*) lateral moraines, which lie along the sides of the valleys for considerable distances above the terminal moraines which they join below. There are often subordinate lateral and terminal (recessional) moraines inside the outer and major ones. Ground moraine covers the surface more or less generally for some distance above the terminal moraines, and to a less extent just inside the lateral moraines. The abundance of ground-moraine matter over the basins varies widely in different valleys.

7. The glaciated valleys often contain lakes, which range in position from the heads of the cirques to the terminal moraines below. This distribution of lakes is shown in numerous valleys of this region, but nowhere better than in those of South Fork of Clear Creek and Lake Creek, a tributary to North Fork of Clear Creek from the south.

While these are the prominent characteristics of glaciated valleys in general, they are not all conspicuous in every valley which the ice occupied. Some of them are poorly developed, or even absent, where the area of snow and ice accumulation was a broad and shallow basin, rather than a narrow mountain valley, or where the glaciers were small. Some of these features are the result of glacial erosion and some of glacial deposition.

GLACIAL EROSION.

To glacial erosion must be ascribed (1) the development of the cirques, (2) the cleaning out of the upper parts of the valleys through which the ice passed, (3) the rounding and widening of the valley bottoms, (4) the polishing of the rock surface in the valleys, and (5) the excavation of some of the lake basins.

Erosion in the cirques.—The cirques are perhaps the most striking result of the erosive action of the ice in these mountains. The distinction between valleys with cirque heads and those without them may be appreciated by a comparison of the topography about the 10,545 and 10,307 foot peaks near the head of Middle Fork of Crazy Woman Creek with that about the 12,271-foot peak just north of the head of South Fork of Clear Creek. Had the mountains of the first-named locality given rise to vigorous glaciers, the heads of the valleys would doubtless be similar to those of the other locality.

The pronounced cirques of the range are centered about its higher part, from South Fork of Clear Creek to North Fork of South Piney Creek on the east side, and from the northern tributaries of East Tensleep Creek to the head of Paintrock Creek on the west. The more conspicuous ones are well shown on the topographic map (Pl. XXVI).

The manner in which cirques are formed has been described elsewhere[a] with especial reference to these mountains. It is sufficient to say here that before the ice affected the mountains the valleys were probably comparable to other mountain valleys which have not been glaciated, and that the tendency of the ice and the attendant weathering was to wear the heads of the valleys back farther and farther into the mountains and at the same time to increase their depths.

It is not generally possible to determine just how much a cirque was deepened by the ice, or how far it was worn back into the mountain. The cliff at the head of the cirque west of the head of South Fork of Clear Creek is about 1,600 feet high, and those at the heads of cirques 7 and 17 (see Pls. XXVI and XXIX) are about 1,500 feet high at a maximum and are often nearly vertical (75° or more). While these figures are in excess of the amount of downward erosion by the ice in the cirque, they nevertheless give some idea of the effectiveness of ice wear under the conditions which existed in these mountains. Cirques were widened as well as deepened. A little more widening of cirques 28 and 29 would have eliminated the divide between them and the two would have become one. Such is the origin of some wide cirques, though it is not certain that the Bighorn Mountains furnish illustrations. The length of a cirque may give some suggestion of the distance through which the head of the valley was carried back under the powerful erosive action of the ice, but is not a measure of it, being generally, if not always, excessive. The bottom of a cirque frequently descends by steps, so that the upper part is in topographic unconformity with the lower. Cirques 7 and 14 (Pls. XXVI and XXXI) are illustrations. Lake basins are sometimes gouged out below the steps.

Cirques were not developed at the heads of all the valleys which contained glaciers. Indeed, in some cases there is little evidence of glaciation at the heads of valleys in which ice movement was pronounced below. This was the case, for example, in some of the southern valleys (1, 2, and 3, Pl. XXVI) which contributed to the ice of the East Tensleep glacier, in some of those (especially 8) which contributed to the West Tensleep glacier, in most of those on the north side of both main divisions of the Paintrock glacier (18 to 21 and 30 to 35), and in most of those which fed the South Medicinelodge, Dome Lake, Tongue River, and Shell Creek

[a] Matthes, F. E., Glacial sculpture of Bighorn Mountains, Wyoming: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 167-190.

glaciers. The perfection of the development of cirques seems to have been dependent on the strength of the glaciation. In most cases weak glaciers did not develop them and strong ones did; but to this general rule there are some exceptions, for the small glacier at the head of Middle Fork of Clear Creek developed a perfect little cirque, while other basins which sent out much ice (notably 30 and 31, Paintrock glacier) did not. The topography and the structure of the rock at the heads of the valleys were the other factors which appear to have influenced the development of cirques, and where these were unfavorable even severe glaciation did not produce such results. During the development of the cirques, and as a part of the process, the upper ends of the valleys were cleaned out and the surface of the solid rock over which the ice moved was smoothed and polished. The cleaning out of the upper ends of the valleys is as a rule more conspicuous where the glacier was confined to a narrow valley, though to this there are exceptions, as shown on the north side of the Paintrock glacier (30–32). Most of the well-developed cirques were cleaned out (Pl. XXXIII *B*), and it is in them that the evidences of ice erosion are most obvious. Most of the cirques within 3 miles of Cloud Peak and some of those farther south (4, 5, 10, 13, and most of those on the east side of the range) are not only well cleaned out, but the bare rock of their bottoms and sides is polished, striated, and grooved, and projecting masses are reduced to roches moutonnees. In some places the finer markings have been obscured by post-Glacial weathering, and in others post-Glacial talus from the cliffs above has covered the bare rock which the ice left.

Another evidence of glacial erosion is found in the numerous rock basins of the glaciated valleys, especially those which head in cirques. Some of these basins were probably gouged out at the bases of the steep slopes at the heads of the cirques; but since the upper end of a cirque retreated as glaciation progressed, the basins developed in this way are not all confined to the present heads of the cirques, and some of them were probably at the outset developed below the heads of the cirques. The rock basins are often irregular, the borders of the lakes which fill them being marked by miniature capes, headlands, and peninsulas of resistant rock, while bare knobs of rock often appear as islands in the lakes.

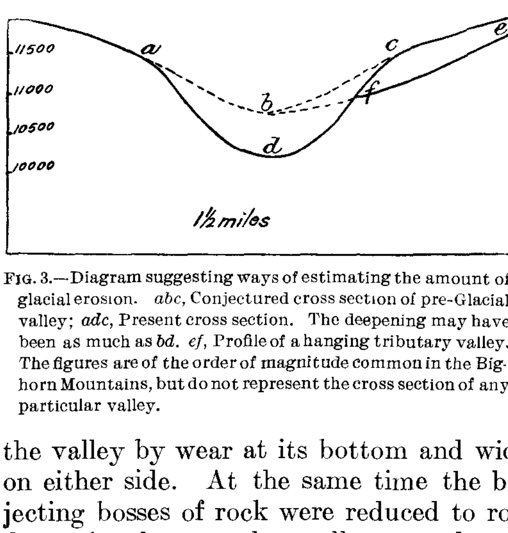
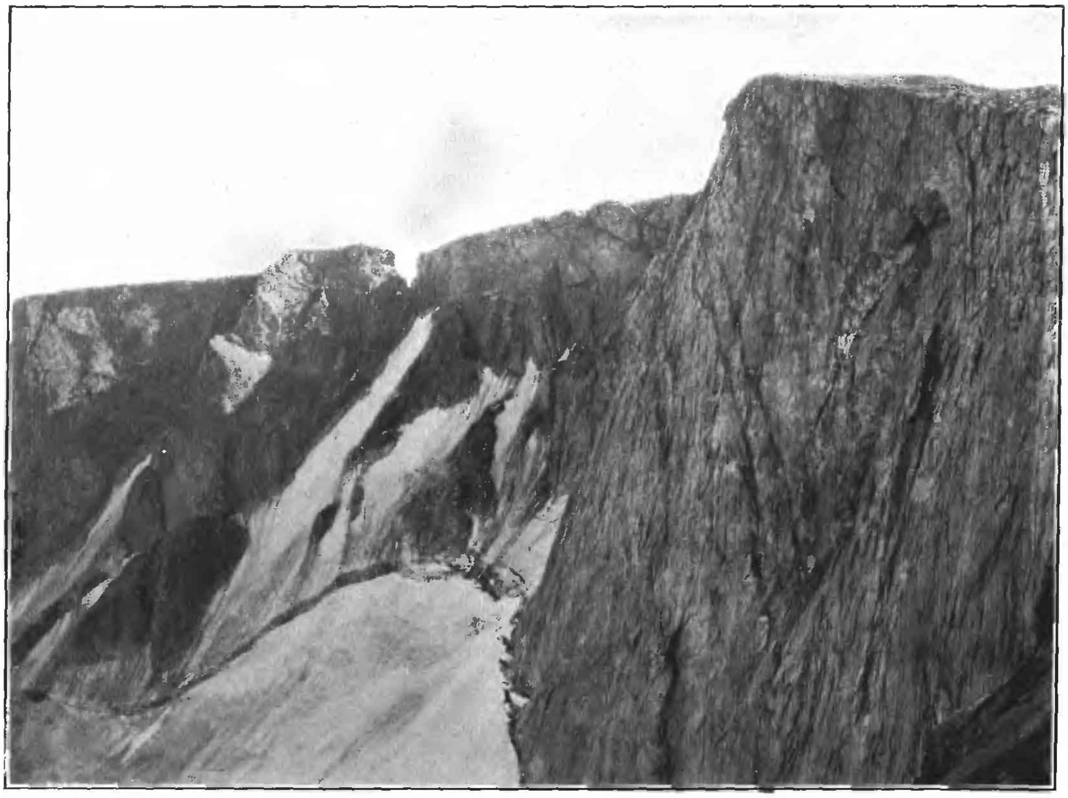


FIG. 3.—Diagram suggesting ways of estimating the amount of glacial erosion. *abc*, Conjectured cross section of pre-Glacial valley; *adc*, Present cross section. The deepening may have been as much as *bd*. *ef*, Profile of a hanging tributary valley. The figures are of the order of magnitude common in the Bighorn Mountains, but do not represent the cross section of any particular valley.

Erosion below the cirques.—As the ice moved down a valley, it not only gathered and carried in its bottom the loose débris of the lower slopes and bottom of the valley, but by means of the débris which it carried it deepened the valley by wear at its bottom and widened it by wearing back its lower slopes on either side. At the same time the bottom and sides were smoothed, and projecting bosses of rock were reduced to roches moutonnées. It is rarely possible to determine how much a valley was deepened by glacial erosion, but some idea of the deepening may be gained by a study of the slopes, as suggested by fig. 3. On this basis Mr. Blackwelder estimates that not a few of the valleys may have

A. GREAT NORTH-FACING CIRQUE AT HEAD OF EAST PRONG OF WEST TENSLEEP CREEK.

Glacial erosion in granite; characteristic frost-heaved rock in foreground. Looking southeast toward summit, 12,292 feet above sea level.



B. NEAR VIEW OF GREAT GRANITE CLIFF ON EAST SIDE OF CLOUD PEAK, BIGHORN MOUNTAINS.

Shows top of glacier. Looking south.

CLOUD PEAK, THE CULMINATION OF THE BIGHORN MOUNTAINS.

Showing glaciated topography with lake basins at head of south prong of South Fork of South Piney Creek. The peak is in the distance just to the right of the high blunt knob. The gap on extreme left is at head of Paintrock drainage of west slope. Looking west.

been deepened 400 to 700 feet in their upper parts, while in some cases, as in the cirque 3 miles north-northeast of Cloud Peak, the deepening may have been considerably more. An idea of the amount of deepening may sometimes be obtained from the topographic unconformity between the main valley and its tributaries. Tributary valleys which end high above the level of the main valley are called hanging valleys (fig. 3), and, while they are not very common in the Bighorn Mountains, illustrations are found at several points. Among the more conspicuous examples are the three cirques leading north from the highest part of the range to North Fork of South Piney Creek, all of which are 500 to 700 feet above the main valley, and the cirque just west of the 12,271-foot peak in the basin of the West Tensleep. In some places glaciers appear to have eroded little. Near the point where the 9,500-foot contour crosses Medicinelodge Creek is an area where the ice failed to remove all the decayed rock, though rock surfaces close by show severe wear. Such cases are so exceptional as to be conspicuous. Glacial erosion was particularly severe in the valley south of Dome Lake, where most of the lakes probably occupy rock basins. The Tongue River glacier did not greatly alter the topography of its valley

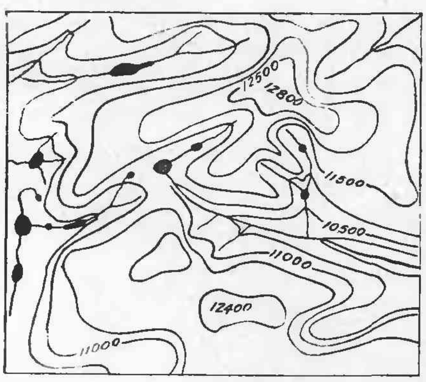


Fig. 4.—Conjectured pre-Glacial drainage about the heads of North Fork of Clear Creek and East Tensleep Creek.

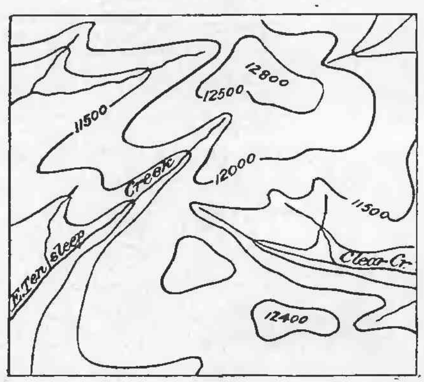


Fig. 5.—Present drainage about the heads of North Fork of Clear Creek and East Tensleep Creek.

and no considerable part of the basin was well cleaned out by the ice. The same was the case with the Willitt glacier, though in this area the erosion was sufficient to round some of the irregularities into roches moutonnées.

Changes in drainage.—Glacial erosion sometimes effected changes in drainage. These mountains present an example of what may be called glacial piracy at the head of North Fork of Clear Creek.[a] The course of the uppermost 1½ miles of the valley of this creek indicates that it was developed by a tributary to Tensleep Creek, and that its present course is secondary. Near the elbow of the creek striæ show that the ice of the cirque in which the creek heads followed the original course of the drainage and joined the Tensleep glacier. It appears that the divide between the two creeks was cut back by the cirque-developing activity of the glacier which occupied North Fork of Clear Creek until it reached the channel of Tensleep Creek. When the ice disappeared, the drainage from the upper part of the former Tensleep Valley found its way by a sharp turn into the valley of North Fork of Clear Creek. Fig. 4 illustrates the conditions as they are conceived to have been before the piracy.

[a] Matthes, F. E., op. cit.

GLACIAL DEPOSITS.

As already stated, the drift was deposited chiefly near the borders of the ice, and now lies largely in terminal and lateral moraines. The size of such moraines has some relation to the vigor of the glaciation, and so to the effectiveness with which the upper parts of the valleys were eroded. Thin and weak glaciers, such as many of those in the northern portion of the area, eroded their channels to a less extent than did most of the glaciers of the Cloud Peak region, and developed less massive moraines, even when they gathered material from a greater area.

Lateral moraines.—Lateral moraines usually become prominent about the locality where the upper and deeper part of a glacier's valley or basin joins the shallower part below, or, in other words, where the glacier emerges from its upper canyon. In the Bighorn Mountains this is usually at an altitude of about 10,000 feet. The lateral moraines often appear first just where the rock ridges which confined the glacier break down. From their upper ends the lateral moraines, one on each side of the glaciated valley, are generally continuous down to the terminal moraines which they join. The position of the heavier lateral moraines is shown on the map (Pl. XXVI).

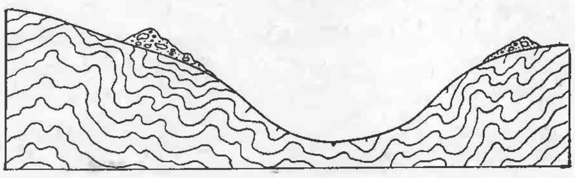


FIG. 6.—Diagram illustrating cross sections of lateral moraines.

The characteristic features of a well-developed lateral moraine are (1) a relatively narrow and even crest (fig. 8); (2) a long slope toward the valley and a short slope in the opposite direction, giving the moraine an unsymmetrical cross section (fig. 9); (3) an outer slope, about as steep as the drift will lie. The inner slope is much more variable, often less steep and more undulating, especially if the drift is thick.

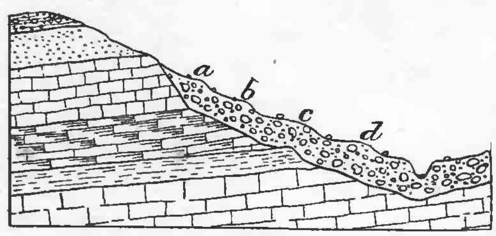


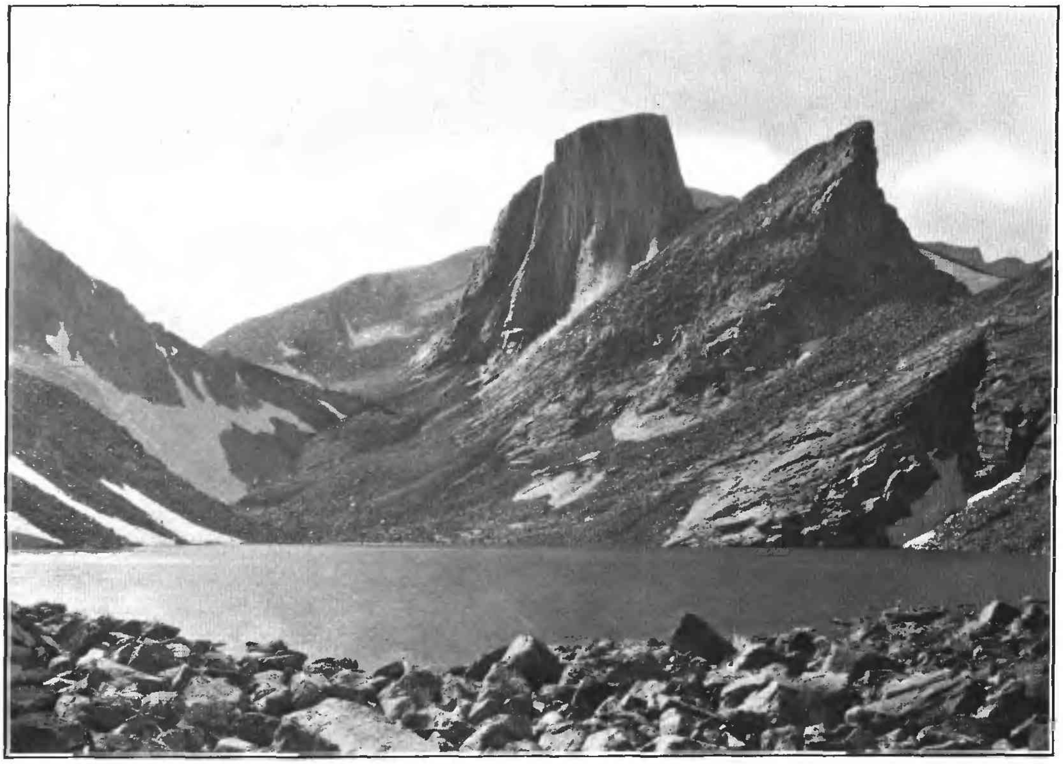
FIG. 7.—Diagram illustrating a terraced lateral moraine as seen in cross section. Four different terraces are shown by the letters.

The lateral moraines sometimes depart widely from this ideal form. Though their crests are often so even as to look like railway grades when seen from a distance, their surfaces, seen at close range, are usually marked by some unevenness. This is especially the case where the moraines widen into broad ridges. Among such irregularities depressions are more conspicuous than elevations. In some cases lateral moraines take the form of benches, or terraces, against the valley slopes. This is well seen, for example, in some places (latitude 40° 20′) on the west side of the valley occupied by the Paintrock glacier. The lateral moraines, whatever their form, are subject to interruptions. Their absence here and there is usually assignable to some peculiarity of topography, often a slope too steep to allow the lodging of drift.

The stronger lateral moraines of this region are the following: (1) Those of North Fork of Clear Creek, especially that on the south, the crest of which rises some 600 feet above the creek within and 150 to 200 feet above the surface without. Its

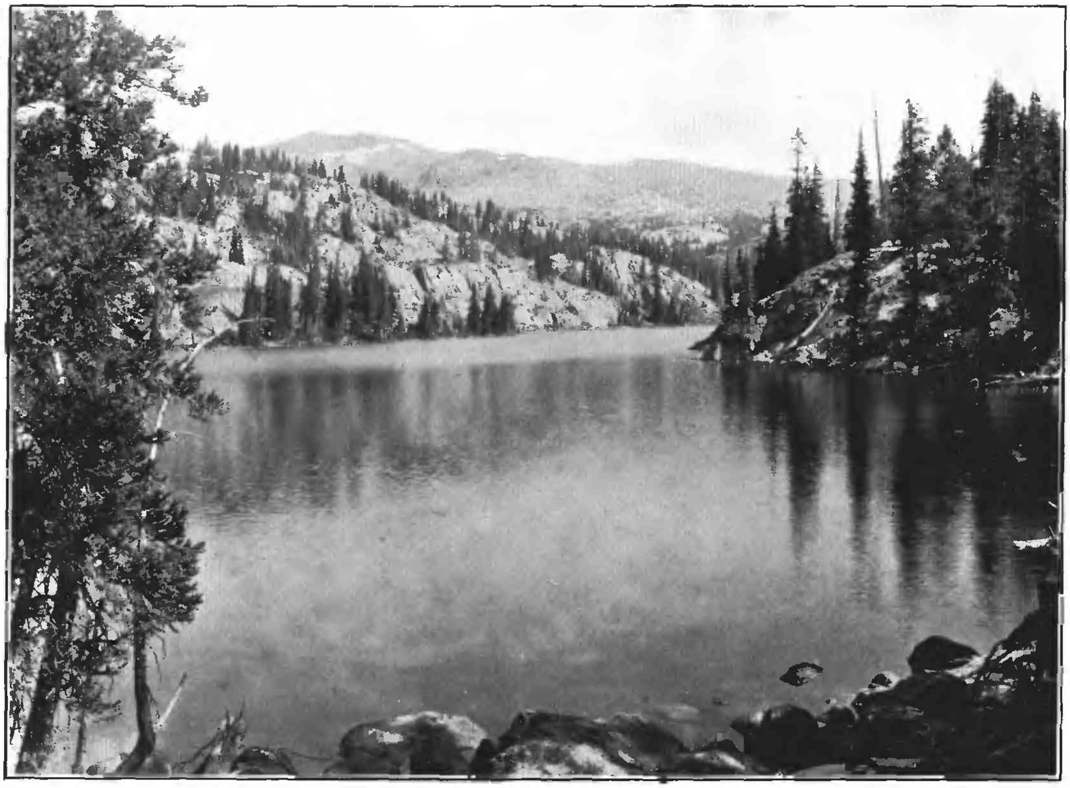
A. SMALL LAKE NEAR HEAD OF NORTH FORK OF SOUTH PINEY CREEK; ALTITUDE, 9,500 FEET.

Cloud Peak is seen in distance through gap to left of center. The characteristic cirque in center contains a small glacier. Blacktooth to right of center. Looking south. Photograph by J. Stimson.



B. HEAD OF SOUTH PRONG OF SOUTH FORK OF SOUTH PINEY CREEK, ABOVE MEADE LAKE.

Remnant of cirque to left, beyond which is head of Middle Fork of Paintrock Creek. Gap is due to the encroachment of two cirques. Cloud Peak lies behind high point slightly to right of middle of picture. Lake in characteristic rock basin in foreground.



A. LAKE DUE TO MORAINE ON EAST PRONG OF WEST TENSLEEP CREEK, ALTITUDE, 9,600 FEET.

Looking northeast toward peak, 12,410 feet above sea level.

B. MORAINAL LAKES ON UPPER SLOPES ON WEST SIDE OF BIGHORN MOUNTAINS.

Region is granite, covered by glacial drift. Paintrock Lake in distance to right. Looking west to Black Butte in distance.

inner face is marked by subordinate (recessional) lateral moraines at some points. The north lateral moraine of this glacier is also well developed, its inner slope being often noticeably undulating. (2) Those of North Fork of South Piney Creek, especially that on the south, which, next to the south lateral moraine of North Fork of Clear Creek, is the strongest lateral moraine on the east side of the range. It has a maximum inner slope of 600 to 700 feet and an outer slope of 100 feet. (3) Those of the West Tensleep glacier, the west lateral moraine being the longest (about 10 miles) in the range. Its upper end has an altitude of about 10,100 feet and it descends to about 8,200 feet. The moraine determined the position of a drainage line (Dry East Tensleep Creek, intermittent) for some distance. The east lateral moraine of this glacier is less strong, with a broad crest and an undulating inner slope. (4) Those of the North Medicinelodge glacier, the northern moraine especially having a well-developed crest line for 1½ miles, below the 9,000-foot contour. (5) Those of the Paintrock glacier, the inner faces of which are terraces. (6) Those of the South Medicinelodge glacier, especially that on the west above Black Butte.

Lateral moraines are poorly developed in the Dome Lake basin, but they are distinct on the northwest side for a mile or more above the terminal moraine, and on the south side of the east lobe. Lateral moraines of the Willitt glacier appear on both sides of the valley, but they are nowhere massive. Down the valley they merge into the terminal moraine. In the basin of South Fork of Tongue River the lateral moraines are feeble, though the one on the west serves as a barrier for a small lake. In Shell Creek basin the north lateral moraine is not strong, though readily traced for several miles east of the crossing of Willitt Creek. It often lacks the well-defined ridge characteristic of lateral moraines. The south lateral moraine has better definition east of the stage road. For some distance it caps the crest of a rock ridge which seems to have been just high enough to keep the ice from spreading southward. Where the south edge of the glacier crossed the tributary valley developed along the outcrop of the weak Cambrian shales it moved up the valley for a short distance, leaving a well-defined terminal moraine. The ice, and later the moraine, ponded the valley, making a small lake which has now vanished. Below this point the lateral moraine is not well defined, the topography through the Paleozoic terranes not being such as to favor the lodgment of drift, especially from a weak glacier. Furthermore, wash and slumping have obscured the limit, which may have been formerly better defined than now. In several places along the south side of this glacier talus from the Paleozoic formations has covered the edge of the drift completely. Lateral moraines are well marked, though not of great size, on both sides of both lobes of the Lighter glacier. Below the union of the two glaciers there is an interlobate or medial moraine, made by the union of the adjacent lateral moraines of the converging glaciers. To the north it merges into the ground moraine.

The west lateral moraine of Big Goose Valley obstructs two creeks, and the east lateral moraine of Cross Creek Valley obstructs one, giving origin to small lakes. The lateral moraines merge into the terminal below, with no sharp line of demarcation.

Interlobate or medial moraines.—Several pronounced moraines appear along the lines of junction of coalescing glaciers. In some instances they take the form of two contiguous lateral moraines, with a distinct depression between, though this is not always the case. Examples of medial moraines are best seen, (1) in the valley of South Fork of Clear Creek, (2) in the midst of the area covered by the West Tensleep glacier, where the two coalescing lobes were separate only in their basal parts, (3) in the basin of the Paintrock glacier below the upper nunatak (an unglaciated hill which rose through the ice), and (4) in the valley of East Fork of Big Goose Creek, where the two lobes of the Lighter glacier united.

Terminal moraines.—Terminal moraines differ notably from lateral moraines in topography, their surfaces being characterized especially by knobs and kettles and by short ridges and troughs of unequal heights and depths. They are generally much broader and more massive than lateral moraines. Approached from the down-valley side the terminal moraines appear as plugs in the valleys, often presenting steep fronts, sometimes 500 feet high, as in the Sherd Lake Valley. The angle of slope is often as much as 30°, and sometimes even a little more. The inner slope is less steep than the outer, and the descent is notably shorter, usually less than 100 feet. The undulations of the surface often amount to as much as 100 feet.

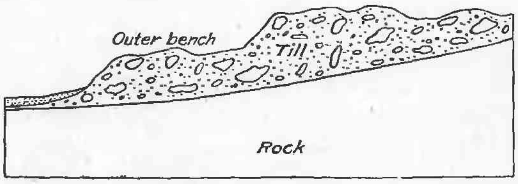


FIG. 8.—Diagram showing the general position of a terminal moraine in a mountain valley.

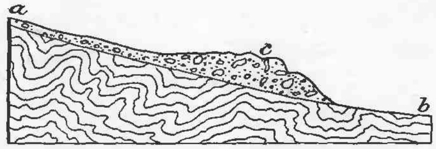
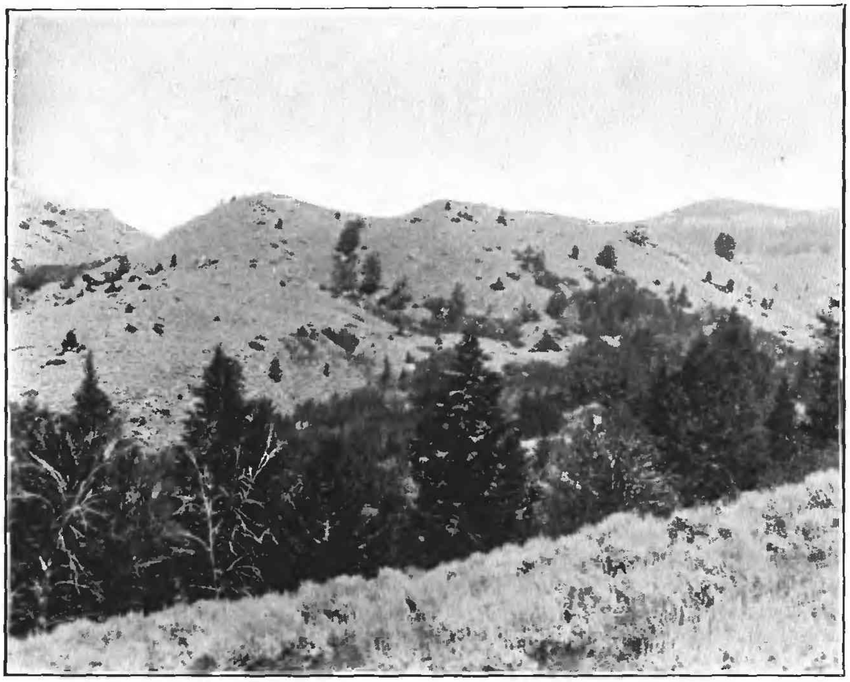


FIG. 9.—Diagrammatic cross section of a terminal moraine, showing the outer bench, as seen in several of the terminal moraines on the east side of the range; glacier movement from *a* to *c*.

A somewhat persistent feature of the terminal moraines on the east side of the range is an outer bench (fig. 9) below and beyond the main summit. The bench is usually less than half a mile wide, and appears to indicate that the ice receded from its position of maximum advance before making its final stand and its main terminal deposit. On the Dome Lake moraine the outer bench has two lakes in depressions in the drift. On the west side of the range these outer benches are not so marked, but the terminal moraines often have two crests, one a mile or less within the other. These double crests on the west may have the same significance as the outer benches on the east. The outer slope of the moraine on East Fork of Goose Creek is marked by a bench less than half way up.

Where the glaciers descended below the area of crystalline rock into the zone of the Paleozoics they entered narrow valleys in the latter, and in such places their terminal moraines are not strongly developed. This was the case, for example, in the valleys of several of the larger glaciers on the west side of the range. The ends of the narrow tongues of ice in such valleys may have oscillated more than the larger ends of the other glaciers and so developed broad rather than high terminal moraines. The narrowness of the valleys also had much to do with the smaller development. The more massive terminal moraines of this area are on the east



A. OUTER FACE OF THE TERMINAL MORAINE OF WEST TENSLEEP GLACIER.

Photograph by E. Blackwelder.

B. NORTH LATERAL MORAINE OF MEADE LAKE GLACIER.

Photograph by E. Blackwelder.

side of the range. That of South Fork of Clear Creek has been mentioned. No other moraine of the range has a longer or steeper outer slope and none has a rougher topography. Its undulations of surface are as much as 100 feet, at least. The terminal moraine of North Fork is about 300 feet above the valley outside, and its topography is very irregular. It has a well-developed outer bench, about one-third of the way up the slope. The terminal moraines of the Meade, Kearney, East Tensleep, South Medicinelodge, and Trapper glaciers have outer faces 150 to 200 feet high, and the topography of most of them is strongly relieved. Even where the moraines are not so high their surfaces are often very rough. The terminal moraine of the Paintrock glacier is relatively small and seemingly out of keeping with the size of the glacier. The terminal moraine of the West Tensleep glacier is wide and massive but not high (see Pl. XXXV, *A*). That of the Willitt glacier has an outer face about 125 feet high and an inner slope about one-third as much. The crest of the terminal moraine of the Lighter glacier is nearly 400 feet above the valley outside and its inner face declines about 50 feet to a broad flat, which probably represents the site of a temporary lake, the basin of which was largely filled by inwash, while ice lay in the valley below. The moraine is rather massive and has characteristic hummocky topography, with a surface relief of 30 to 40 feet. In the Dome Lake area the terminal moraines are distinct, but not massive, both at the main northern terminus and at the end of the little offshoot east of Heart Lake. In both of these places they have the characteristic rough, hummocky, kettle-shaped surface. The kettles of the main moraine are sharply marked, depths of 30 to 50 feet, and slopes of 35° to 38° being not infrequent. The moraine on South Fork of Tongue River has a height of only 30 to 40 feet. Conforming to the shape of its valley, the Shell Creek glacier became pointed below and, since it was also thin, its terminal moraine is weak. Its relief is only 10 or 15 feet, and it differs from the moraines farther east in that it contains Paleozoic material. The terminal moraine of the glacier in the valley of North Fork of South Piney Creek rises about 200 feet above the valley outside and, as in many other cases, there is a moraine bench about half a mile wide on its outer slope about 90 feet below the crest. Recessional moraines occur in a number of the glaciated valleys, but they are not generally conspicuous. They often obstructed drainage temporarily and gave rise to lakes, most of which have now been drained or filled. No distinct recessional moraine appears in the basins of Shell Creek and South Fork of Tongue River.

Lateral moraines not only grade into terminal moraines as they descend, but in some places the distinction between the two types topographically is lost. There appears to have been a sideward motion along the edges of even the narrowly confined valley glaciers, and the massive lateral moraines were accumulated largely beneath the sideward-moving edges. Where the edge oscillated in position the lateral moraine simulates a terminal moraine, and this is often true of the inner slopes where it is not of the crest and outer slope.

Ground moraine.—The thick drift inside the lateral and terminal moraines is mostly ground moraine, which has less distinctive topographic characteristics than the lateral and terminal moraines. It generally covers considerable areas inside the terminal and lateral moraines, and occurs in smaller patches, even to the heads of many of the glaciated valleys. The map (Pl. XXVI) shows in a general way where the drift is thick. Ground-moraine matter is more widespread in valleys in which glaciation was feeble than in those where it was vigorous. Where the ground moraine is meager, the bottoms of the valleys are often a succession of bare roches moutonnées, rising above the intervening depressions which have soil enough to support vegetation. In the upper part of Shell Creek basin there is relatively little drift, but it increases in amount below, though, except near the principal moraines, it nowhere conceals the rock for large areas. In the basin of the Willitt glacier the rock is relatively bare above an altitude of 9,500 feet, but lower down it is more and more covered by drift. In Big Goose Valley ground moraine covers a part of the area within the moraines and probably is as nearly continuous in this basin as in any, but rock exposures are frequent. In the basin of South Fork of Tongue River drift is prevalent, but it is rarely thick enough to conceal the topography of the rock beneath.

Composition of the drift.—The drift in the Bighorn Mountains differs in no essential respect from the drift of other mountain-valley glaciers, unless it be in the rocks which enter into its composition. On the east it consists wholly of igneous and metamorphic rock, derived from the axis of the range. On the west, where some of the glaciers descended to the Paleozoic formations, materials from them are mingled with rocks derived from the higher part of the range.

The drift, like that of mountains in general, is coarse. Bowlders are the most conspicuous constituent, and they range in size up to 40 feet in diameter, though those more than 10 or 15 feet in diameter are rare. Most of them are of light-colored rock, and their smooth, unetched surfaces, mainly free from lichens, give to the surface of the moraine a whiteness which is often conspicuous, even at the distance of several miles.

Thickness of the drift.—The actual thickness of drift is not easily determined in many places. The heights of the terminal moraines, as seen from the outside—500 feet and less—probably represent the maximum thickness of the drift. The post-Glacial cuts of the streams through terminal moraines, rarely more than 150 feet deep, do not reach the bottom of the drift.

Changes of drainage.—Greater changes of drainage were effected by the deposition of drift than by glacial erosion. While these changes are mostly slight, a few of them may be mentioned as illustrations.

Sherd Lake Valley probably drained into South Fork of Clear Creek before the massive moraine diverted it to Middle Fork. The glacier of North Fork of Clear Creek seems to have been directed down the valley of French Creek, as if that were the former outlet for the upper portion of this valley. The east lateral moraine of Kearney glacier shifted South Fork of South Piney Creek to the east. The creek doubtless followed the edge of the ice while the glacier existed, but later crossed the lateral moraine to North Fork. Drainage from the Paintrock Lakes region was probably formerly southwestward to Medicinelodge Creek. There were other minor changes of the same general type.

The drainage of the Dome Lake Basin was somewhat deranged by the ice. The lower course of the tributary stream which joins the main creek at the crossing of the stage road west of bench mark 7998 appears to have been shifted northward by the

A. GLACIER IN HEAD OF CIRQUE ON EAST SIDE OF CLOUD PEAK.

Shows moraine and lake. Cloud Peak is high point to left. Looking southwest.

B. GLACIER ON EAST SLOPE OF PEAK NORTH OF CLOUD PEAK.

Crest of Bighorn Mountains, at head of south prong of North Fork of South Piney Creek; looking southwest. Granite with glacial topography. Photograph by J. Stimson.

deposition of the terminal moraine, though the displacement was probably not more than one-fourth of a mile. The drainage east of Heart Lake also was probably shifted from its former course. The eastward drainage at this point was probably northwestward to West Fork of the Big Goose in pre-Glacial time. Just west of its terminus this glacier obstructed a tributary valley, causing a shallow lake which was largely filled by wash from the ice.

It is probable that the course of Willitt Creek was slightly changed in section 15 by the deposition of the drift. Formerly it probably continued southward through this section, joining the main valley farther south than now. A notable change of drainage due to moraine is in the diversion of Cross Creek into Little Goose Creek from its probable former course into Big Goose Creek.

Striæ.—Glacial striæ, grooves, and all other familiar types of glacial scoring are found at one point or another in the glaciated valleys, but they possess no peculiarities which demand consideration here. Their directions were controlled primarily by topography. The courses of a few of them are shown on Pl. XXVI.

Nunataks.—Within the glaciated area two small tracts were found which appear to have been surrounded but not covered by the ice. One lies in the area of the Paintrock glacier. The ice on the sides of the valley reached heights as great as that of this hill, but the hill itself shows no evidence of glaciation. Against one side of it there is a lateral moraine. The second area is in the upper part of the same basin, but in this case the ridge rises far above the level attained by the ice.

Nivation.—Under this term Matthes[a] has described certain phenomena of these mountains which deserve mention here. In many valleys and against many cliffs where glaciers, or at any rate well-defined glaciers, did not exist, snow accumulated in quantity. In some cases the snow merely made great snowdrifts, many of which no doubt persisted from year to year. Beneath and about the snow there was deposition of fine material washed down from above, while the snow itself tended to prevent the removal of the loose material beneath it. The result was a large accumulation of such material. This process has been called nivation. Where cliffs projected above the drifts of snow débris from them rolled down over the snow banks and often lodged below.

Though the snow and ice in such positions often had no motion, in some cases it was probably otherwise. It is conceived that this motion was occasionally incipient glacier movement, too feeble to leave demonstrative record of itself; that in others it was a slow creep, such as is likely to affect all great masses of snow on slopes, and that in still others there was doubtless sliding. Furthermore' the accumulated débris itself was subject to sliding, and the fine mud even to flowing, during the summer seasons when the edges of the accumulation were free from snow and ice and unfrozen. The mass also expanded on freezing at the end of summer. It has continually undergone most of these changes ever since the ice epoch, and the result has been the accumulation of débris, not distinctly glacial, but with striking peculiarities of topography, being often slightly ridged, sometimes marked by low mounds, occasionally simulating mud streams, etc. Phenomena of the same sort elsewhere have been called "talus glaciers."

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[a] Matthes, F. E., op. cit.

Nivation characterizes the heads of some valleys which were distinctly glaciated below. Such valley heads are not cirques. Some of the heads of both the East and West Tensleep glacial systems afford illustrations. Nivation is also marked in many valleys where there is no evidence of distinct glacial movement. It appears to have affected the inner slope of the west lateral moraine of the West Tensleep glacier since the ice retired, and is in progress now at other points.[a] Several areas of nivation are shown on the map, and there are doubtless others not represented.

THE LAKES.

The lakes of the Bighorns are all due directly to glaciation. The basins of some of them were due to glacial erosion, those of others to glacial deposition. Of the latter, some lie just outside the moraines, but more within. Of those outside, Elk Lake, east of Cloud Peak, is the largest. While the ice lay in the valleys to the north it obstructed the drainage of the basin above the lake, and when the ice melted its lateral moraine continued the obstruction. Numerous lakelets were formed in similar situations, but most of them have been drained. The sites of several such lakes, now flat meadows, are shown on the map, the largest being east of the Tensleep glaciers.

Of lakes within terminal moraines there are several types—(1) those in rock basins, (2) those in basins made by drift dams, (3) those in basins which are partly

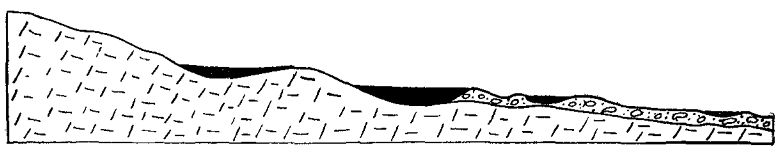


FIG. 10.—Diagrammatic section illustrating various types of lake basins.

of rock and partly of drift, and (4) those which lie in depressions in the drift itself. The several types are illustrated diagrammatically by fig. 10.

Probably half the lakes and ponds of the range large enough to be represented on the map occupy rock basins. Lakes of this class are especially numerous in the upper parts of the glaciated valleys west and southwest of Cloud Peak and on the east side of the range. In many cases bare rock may be seen continuously around the shore of the lake, while in others the rock of the shore is somewhat covered by drift, but in such relations as to leave no doubt as to the nature of the basin. The lakes in the heads of the cirques are mostly in rock basins, though such basins are not confined to that position.

Most of the larger lakes, such as East and West Tensleep lakes and Lake Solitude, are probably held in by drift dams, or at least have their basins made deeper by the building up of their rims by drift. The Paintrock Lakes are examples of lakes held in, largely at least, by drift dams, and most of the lakes which lie just above the terminal and recessional moraines belong to the same category. Many of the small ponds, especially in terminal moraines, occupy depressions in the surface of the drift. The depths of the lakes have not been determined.

[a] Matthes, F. E., op. cit., p. 180.

All the lakes in the area of the western arm of the Dome Lake glacier appear to be in drift basins or to be held in by drift dams. Dome Lake appears to occupy a drift basin, and its outlet has been lowered but a few feet since the beginning of its history. The lake is being gradually filled by a delta at the débouchure of its inlet. Four small flats within the area of this glacier (see map, Pl. XXVI) represent old lake basins.

Lake Adelaide and the associated ponds probably occupy parts of pre-Glacial valleys obstructed by drift. All the lakes are now being filled.

The north margin of the Shell Creek glacier obstructed several ravines on the north, forming basins which were occupied by small lakes. These became extinct, partly by filling, and partly by the erosion of their outlets. Their sites are shown on the map.

DEPOSITION BY GLACIAL WATERS.

The streams which carried off the water from the melting glaciers carried bowlders, gravel, and finer material down the valleys, developing valley trains. Though generally distinct for a short distance below the moraines, such trains are usually surprisingly small. This is primarily the result of slight development, not of subsequent removal. On the west side of the range, where most of the glaciers ended in canyon-like valleys, the valley trains are so poorly developed that they have been omitted from the map. Elsewhere their remnants appear as low terraces. A narrow valley train extends down Big Goose Valley below the terminal moraine. At the moraine its gradient is steep, but the slope diminishes downstream. A second slight valley train descends the valley of Cross Creek east of the terminus of the glacier. A small amount of gravel washed out from the moraine appears along North Fork of South Piney Creek below the moraine. It is probable that the streams were so swift at the time the ice was melting that all fine material was carried and distributed far below the moraines. Throughout the whole region, however, the amount of fluvio-glacial material which can be connected with the late glaciation is remarkably small.

Drainage from the ice helped to fill some shallow lake basins developed just outside the glaciers, where the ice and later the lateral moraines obstructed the drainage. The larger lake flats of this type occur east of the East and West Tensleep glaciers, respectively.

Running water also made some deposits inside the moraines after the glaciers retreated from their most advanced positions. Such deposits are usually not conspicuous, except where the drainage entered lakes. In some cases shallow lakes appear to have their basins filled by inwash. Soldier Park, in the valley of North Fork of Clear Creek, is a good example. Others of some size occur above the terminal moraine of the Kearney glacier and in the upper part of the basin of the East Tensleep glacier, and there are smaller ones at many other points.

POST-GLACIAL CHANGES.

Few changes have taken place since the ice disappeared. The freshness of the drift and of the glaciated rock surfaces is among the most striking features of the valleys which were occupied by ice. The changes include (1) weathering, especially that resulting from changes of temperature, and (2) stream erosion, especially where the creeks cross the terminal moraines. In several cases lakes have been lowered by the lowering of their outlets.

In general the amount of talus which has been split off from the rock walls in post-Glacial time is not great, but there are some striking exceptions. Matthes cites an instance where a trail through the pass at the head of North Fork of Clear Creek, in use but ten years before, had been abandoned (1899) because of the accumulation of talus. The amount of post-Glacial talus is also great at the bases of not a few cirque cliffs, as at the heads of the Kearney glacier, in cirque 4 of the East Tensleep glacier, where the talus from opposite sides meets in the bottom of the valley, and in cirque 6 of the West Tensleep glacier. Where the amount of post-Glacial talus is great, it is usually at the bases of cliffs which escaped severe glaciation or where they are of rock which breaks up readily as a result of temperature changes. While the post-Glacial results of temperature changes have not usually been great, the fact that they are appreciable is evident on all sides in the exfoliation of bowlders and the surfaces of exposed rock. Advertisements painted on bowlders have been somewhat extensively defaced by the shelling off of the surface on which they were painted. That this and not the weathering of the paint explains their disappearance is certain, because exfoliated shells about the bases of the bowlders and rock walls often show the paint but little dimmed.

Where streams flow over solid rock the amount of work which they have done in post-Glacial time is hardly appreciable. In two cases (cirques 5 and 7) striæ were observed in the channels of streams. The wear in the upper parts of the valleys is very slight, because there is little material fine enough for the streams to carry, all fine material having been removed by the ice.

Where the streams flow in channels in the drift their work has been limited to carrying away the finer material. Even where the streams are swift, the bowlders set free by the removal of the fine material, have accumulated in their channels and offer effective resistance to further erosion. The post-Glacial cuts in the ground moraine are rarely 25 feet deep. Only where streams cross terminal moraines are their gorges pronounced. That of East Tensleep Creek approaches 200 feet as a maximum, and those of West Tensleep and South Medicinelodge creeks approach 150 feet. Of the remaining none are much more than half as deep. All these cuts are V-shaped, with slopes of 25° to 35°.

East and West forks of Goose Creek and South Piney Creek have cut narrow gorges 70 to 100 feet deep where they cross the terminal moraines. Most other streams have done less than this, and except at the moraine crossings their erosive work has been inconsiderable.

TIME SINCE LAST GLACIAL EPOCH.

To casual observers one of the most striking features of the recent glacial drift in the Bighorn Mountains is its freshness. The first impression is that the drift is notably younger than the Wisconsin drift of the interior. This impression is perhaps deceptive, (1) because the rock in this region probably weathers less rapidly than the rock of the interior; (2) because the drift is much coarser than in the interior, so that bowlders are relatively conspicuous; and (3) because the bowlders are largely of light color, and so give the appearance of freshness.

The less rapid weathering of the rock in the mountains is probably the result of the climate. The average temperature is much lower than in the interior of the continent, thus restricting chemical change, and for a large part of the year the bowlders are protected by snow against great changes of temperature. Furthermore, weathering by exfoliation, which is effective in the summer, leaves fresh-looking surfaces. Exfoliation has been too rapid to admit the development about the bowlders of weathered zones, due to the reaction of the atmosphere. The lack or slightness of chemical action is also shown in sections of the drift, for they do not show appreciable leaching, while the drift of Wisconsin age in the northern interior usually shows leaching to the depth of 2 to 4 feet.

EXISTING GLACIERS.

There are numerous perennial snow fields and a few small glaciers in the Bighorn Mountains. The topographic map shows these glaciers on the east side of the range, two at the head of North Fork of South Piney Creek and one at the head of South Fork. The last is much the largest. In 1902 there was a fourth small glacier on this side of the range in one of the southern cirques of South Fork (W. H. Emmons). This glacier and those at the head of North Fork are all very small, though possessing characteristics which indicate glacial movement. The principal glacier at the head of South Fork lies in a cirque the walls of which are nearly vertical and, at a maximum, nearly 1,600 feet high (see Pl. XXXI, *B*). The glacier is therefore well protected from the sun. It has a distinct terminal moraine, 10 to 25 feet high, and a lateral moraine on either side. Its surface carries much dust and is marked by dust walls and bowlder-capped ice pillars. Superglacial streams have cut channels 3 to 4 feet deep, revealing layers of ice, some clean and some débris-charged, which are inclined 20° to 25°. A front view of this glacier is shown in Pl. XXXVI, *A*, but as the photograph was taken from a low level the view is greatly foreshortened. The glacier is about half a mile long.

EARLIER GLACIAL DRIFT.

Besides the glacial drift described above and definitely referred to the last glacial epoch there are various sorts of loose material of the general nature of drift. Some of it is glacial, some of it may have had a glacial origin as far as is now known, and some of it is not glacial. It is not always possible to separate that which is glacial from that which may be fluviatile. Of that which is certainly glacial some is much older than the moraines already described.

At numerous points just outside the terminal and lateral moraines of the last glacial epoch there are limited areas of glacial drift. This extra-morainic drift occurs outside the new moraines of the Kearney, Meade Lake, North and South forks of Clear Creek, East Tensleep, Paintrock, South Medicinelodge, Lighter, Willitt, Piney, and Tongue River glaciers. In its physical and lithological constitution some of it is very like the new moraines. This is especially true of that outside the late moraines of the Tensleep, Paintrock, and South Medicinelodge glaciers (Bastin). But even here it generally has a somewhat older look than the late moraines, due to greater decay and to less abundant surface bowlders, and particularly to the absence of those topographic features especially characteristic of drift and to the presence of drainage lines of mature aspect. The extra-morainic drift on the east and north side of the mountains, on the other hand, has more unmistakable marks of age (Blackwelder), especially in the physical condition of the drift and in the amount of erosion which has taken place since its deposition. The extensive erosion is evident both in the patchy distribution of the drift itself and in the great deepening of the valleys since it was deposited.

Concerning the extra-morainic drift of East Tensleep, Paintrock, and South Medicinelodge basins, it is clear that if it ever had the topography characteristic of the new drift that fact would show its great antiquity. On the other hand, its relative freshness and its limited distribution just outside the new moraines would be consistent with the interpretation that it was deposited during a temporary advance of the ice beyond the position of the main moraines, that it was never more than a thin body of drift, and that it never had the topography characteristic of thick drift. If brought down early in the late glacial epoch, its materials may have been more decayed at the time of deposition than those of the moraines. Furthermore, it is rational to assume that early in the Glacial epoch, before glacial erosion had notably deepened the valleys, the ice spread somewhat more widely, at least laterally, than at a later time, after the valleys had been made more capacious by glaciation. While such an interpretation might perhaps be entertained for the extra-morainic drift of the basins last mentioned, it does not seem to fit that on the east side and north end of the range, where the great age of the drift in question is evident, not only in the topography, but in the physical constitution of the drift and in the erosion which has taken place since it was deposited (Blackwelder). Much if not all of the extra-morainic drift is therefore regarded as the product of an earlier glacial epoch, when the glaciers, especially at the east and north, were somewhat more extensive than those of the last glacial epoch.

The extra-morainic drift shown on the map on the east side of the range is not all known to be of glacial origin, but glaciated bowlders were found in it in the valley of North Fork of Clear Creek nearly 2 miles below the new moraine, on the divide between North Fork of South Piney Creek and North Piney Creek, and on Big Goose Creek. The finding of glaciated bowlders in these several localities, quite out of the range of the ice and of the drainage of the last glacial epoch, demonstrates the glacial origin of at least parts of this drift. If some of it is of fluviatile origin, such drift can not be readily separated from the glacial. The paucity of glaciated bowlders is not strange when the fewness of the exposures and the extent of weathering since this drift was deposited are considered.

The older drift is not continuous over the areas indicated on the map. These are rather the areas within which it is known to occur. Especially between North and South forks of Clear Creek the drift is discontinuous, and within this area no glaciated material was found.

In the valley of North Fork of South Piney Creek is a considerable body of earlier drift. It was apparently deposited by a glacier made up of the union of glaciers from North and South forks of South Piney Creek. The drift is found along both sides of the creek, but to the east it is scattered and ill defined. On the west it is more abundant and its character is better defined. That west of Penrose Park is certainly glacial. Two shallow ponds in Penrose Park may be relics of early glacial topography, but they are the only features of this sort observed.

There are some peculiarities of drainage in this region which perhaps afford an argument for early glaciation. North Piney Creek has only one tributary from the southeast for more than 9 miles and many from the west. It may be that the former tributaries of the North Piney from the east were filled by the older drift, and it is quite possible that the main stream itself was shifted westward at the same time.

The results of weathering and erosion after early Glacial time are seen not only in the destruction of the drift topography, but in the decayed exteriors of bowlders and in their burial, probably often by material weathered from them and by material derived from surface bowlders which have disappeared. Bowlders are everywhere much less prominent on the surface of the old drift than on the new. The relations of the old drift to the rock on Piney Creek are suggested in fig. 11. In general it may be said that the outcrops of rock within the area marked as old drift are rare upstream, but increase in number and in prominence down the valley.

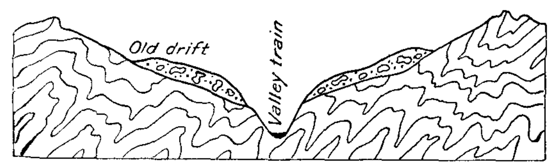


FIG. 11.—Diagrammatic cross section of the valley of South Piney Creek, showing the relation of the old drift on the sides of the valley to the fluvio-glacial drift of moraine (late Glacial) age. The valley in the old drift is some 500 feet deep.

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 (Blackwelder).

There is also a large body of older drift outside the moraine of the late glacial epoch in the valley of East Fork of Big Goose Creek. It extends some 3 miles beyond the new drift, covering a wedge-shaped area down the valley. Similar drift lies outside the new drift on the west, 3 miles above the terminal moraine. The old drift nowhere has the undulatory topography of the new, but it contains glaciated bowlders and in places forms ridges which are perhaps remnants of lateral moraines. An example occurs one-fourth of a mile east of Morrow ranch. It is not certain that all the area mapped as old drift is covered by material deposited directly by the ice, for sections showing the real nature of the material were found at only one point.

Old drift is found again in the valley of West Fork of Big Goose Creek, outside the newer drift. The limits of the extra-morainic drift are obscure, being nowhere distinctly marked topographically, and the area mapped is to be regarded as the area within which it occurs rather than an area entirely covered by it. The original extent was probably greater than the map shows. Glaciated stones are found in this drift three-fourths of a mile beyond the new moraine. The most considerable development of the drift appears to be along the main creek between elevations of 7,500 and 7,800 feet. The drift here appears to be as much as 100 feet thick locally, and has been deeply dissected by valleys which, in their breadth, are in striking contrast with the valleys in the late glacial drift.

There may be a little of the old drift on the east side of the late Tongue River glacier, but in the absence of cuts it could not be certainly identified, and is not mapped. There is probably a large area of it between Shell Creek glacier and Willitt glacier, and north of the latter. Its limits are, however, not well defined, and it was nowhere determined to be glacial. It is so classed, however, on the basis of surface similarity to other bodies of older drift.

HIGHER TERRACE DEPOSITS.

Capping some of the ridges at the foot of the mountain and on the plains eastward are remnants of gravel deposits considerably younger than the supposed Tertiary terraces described on page 67. On the east side of the mountains most of the divides are terraces which extend eastward from the foot of the steeper mountain slopes. They are capped by deposits of gravel and sand from 10 to 40 feet thick, and usually have smooth surfaces sloping gently to the east at a rate which increases in amount toward the mountains and on the highest terraces. The terraces are cut away along the streams which flow out of the mountain canyons, and the mouths of these canyons are from 200 to 400 feet below the terraces in most cases. The most extensive terrace areas at the foot of the mountains are between Tongue River and Little Goose Creek, where they vary from one-fourth of a mile to 3 miles in width. Other areas of large size lie southwest of Buffalo, especially in the vicinity of North Fork of Crazy Woman Creek, where one is traversed by the Crazy Woman road. Many of the terraces extend only a short distance from the base of the mountains, except from Tongue River to Little Goose Creek, where they extend far to the eastward, in part capping divides and in part as a high second bench along the valleys. Most of the larger valleys contain these higher terraces, usually on the north side. West of Buffalo there are two or three high terraces, of which the lower one extends far to the northeast along the west side of Clear Creek Valley. Remnants of a former high terrace cap the ridges on the divide between Crazy Woman and Clear creeks south-southwest of Buffalo. On the west side of the Bighorn Mountains the high terraces occur more widely scattered and mostly in smaller areas than on the east side. The largest areas are along Shell Creek, mainly on its south side, along Beaver and Bear creeks, and on the divide to the west. Two small fragments of red conglomerate lie on the slopes of Shell Creek Canyon near its mouth, about 400 feet above the stream, and smaller areas of similar high-level gravel occur between the head of Red Gulch and South Beaver Creek and capping some high points north and southwest of Cloverly.

These remnants of high terraces on both sides of the Bighorn Mountains indicate a former higher level of deposition, probably of early Quaternary age. Doubtless the deposits were originally much more extensive than they are now. The different heights of the terraces indicate that there were successive stages of progress in valley development, the latest of which is not very remote. Since the time of higher terrace levels the degradation of the plains has amounted to several hundred feet along the valleys.

ALLUVIUM.

In the higher portion of the Bighorn Mountains most of the streams are engaged in erosion, and the slope is sufficient for the detritus to be carried far away. Small amounts of alluvium are deposited along the wider portions of some of the valleys, but they are usually transient and are removed by the heavier floods. In the adjoining plains, underlain by softer rocks, the valleys are wide and alluvial deposits have considerable extent. The bottom lands in the valleys of Tongue River near Ranchester, Clear Creek below Buffalo, Crazy Woman Creek below Hesse ranch, Shell Creek below Shell, and Paintrock Creek below its canyon are often a mile in width. They are nearly level and underlain by from 10 to 50 feet of alluvium consisting mainly of sand and loam with local streaks of gravel. Alluvial deposits of moderate extent occur along all the creeks in the plains and basin area, usually varying in width in proportion to the size of the stream. These deposits constitute nearly level tracts, through which the streams meander from side to side, usually in narrow trenches. In times of flood the water often rises over the banks and deposits more or less alluvium on the bottom lands, so that the accumulation of this material is still in progress.

STRUCTURE.

GENERAL FEATURES.

The Bighorn uplift is an anticline rising steeply out of the nearly horizontal strata of the Great Plains. Its principal features are shown in Pl. XXXVII, which is a diagram of the configuration of one of the prominent formations, not only in its surface outcrops, but in its extension underground and, by a theoretical restoration, over the area from which it is believed to have been eroded in the central portion of the uplift. The diagram covers the entire uplift from the canyon of the Bighorn River southward to Bridger Creek and also the eastern end of the uplift of the Bridger Range. It will be seen from this illustration that the anticline often has steep sides, especially to the east, and relatively gentle dips on top. In the vicinity of Bald Mountain and in the southern portion of the range the crest of the uplift is nearly flat, but in the wide granite area culminating in Cloud Peak there was considerable rise, the total uplift here being about 25,000 feet, considered with relation to the great basins on either side of the mountains. Near the southern end of the uplift there is a local dome of considerable prominence. The bottom of the syncline underlying the Bighorn basin lies considerably west of the area shown in the diagram. The distance from the center of the axis to the east side of the mountain is about 25 miles, so that the upward slope of the deformation is at about the rate of 1 in 5. Subordinate features of structure are local flexures on the flanks of the main uplift and a number of faults. One of the notable separate flexures lies 15 miles east-northeast of Bald Mountain, where an anticline of great local prominence appears. Small branch flexures extend diagonally out of the main uplift at intervals, notably in the slopes southwest of Mayoworth and near No Wood, Bigtrails, Greub, and Shell. West of Cloud Peak the long, gentle western slope of the uplift bears a number of crenulations, one of the most notable of which is at Bonanza. A small local anticline passes near Kaycee and Tisdel's ranch.

The faults are marked features, especially in the region northwest of Buffalo. One of them has a throw of about 9,000 feet, but much of the displacement was effected in Laramie time. These faults extend into the granites east of Cloud Peak, and their course and extent was not determined outside of the areas of sedimentary rocks. North of Rome is a prominent fault varying in throw from 500 to 1,000 feet and extending across the strike for several miles. South of this fault is a great hook-shaped displacement with one fault line extending along the west side of the crest of the mountain to the southern termination of the uplift, and the other fault extending east and southeast out of the mountain. Along the north-south fault there is an uplift of from 500 to 2,000 feet on the east side, while along the other fault there is a downthrow of about the same amount on the west side, so that the faulted block has revolved slightly. The axis of this movement lies near a point (Pl. XXXVII) halfway between Mayoworth and Tensleep. Near the southern end of the uplift the north-south fault divides into several irregular faults.

In the Bald Mountain region there are several local faults with displacements which are mainly along the strike and which follow the steep upturn along the western margin of the uplift. Another local strike fault extends along the east side of Walker Mountain.

FRONT RIDGE SOUTH OF BUFFALO.

Northward from latitude 44° to Clear Creek the front ridge of the Bighorn Mountains is an east-dipping monocline, in which the strata are generally inclined from 10° to 30°. The amounts vary, being greatest north of North Fork of Crazy Woman Creek, and much gentler to the south, especially on Middle Fork of Crazy Woman Creek, where the dips are steep on the mountain slope, but diminish rapidly in amount on the highlands, so that the Deadwood formation is spread out widely in the vicinity of Hazelton. Northwest of Greub the monocline is traversed diagonally by an anticline of moderate prominence, which trends northwest-southeast and passes out of the mountains in a ridge of Tensleep sandstone on Middle Fork of Crazy Woman Creek. It appears first in the Deadwood and Bighorn formations on the upper portion of Billy Creek, the anticline giving rise to a high knob of Madison limestone a short distance south of the canyon. Its most prominent feature, perhaps, is the ridge of Tensleep sandstone near Middle Fork of Crazy Woman Creek, west of which a narrow valley of Chugwater red beds extends some distance northward. The flexure dies out in the red beds a short distance south of the creek. Throughout the course of this anticline the steeper dips are on its west side. On North Fork of Crazy Woman Creek there is an abrupt change in the dip of the beds, presenting the relations shown in Pl. XXXIX, *B*. Along the east side of the ridge the dips are about 15°, but, as shown in the illustration, they suddenly change and become nearly vertical along the crest. Very steep dips prevail from this point northward along the front ridge to beyond Piney Creek.

FRONT RIDGE WEST AND NORTHWEST OF BUFFALO.

Steep dips prevail north of Clear Creek, with local moderate diminution on the slopes west of Mowry basin. In this portion of the region the ridge is traversed by a number of profound faults, partly of Laramie and partly of later age. The first of these from the south develops 5 miles north of Sisters Hill, crosses the front ridge diagonally, and extends along its eastern side for several miles. From Clear Creek to Johnson Creek Kingsbury conglomerate lies in contact with the Madison limestones along this dislocation, as is shown in Pl. XXIV, *B* (p. 70). North of Johnson Creek the fault divides, one branch passing under the Kingsbury conglomerate and the other bringing the Chugwater and Deadwood formations into contact. Near this section another fault develops on the west side of the front ridge, which

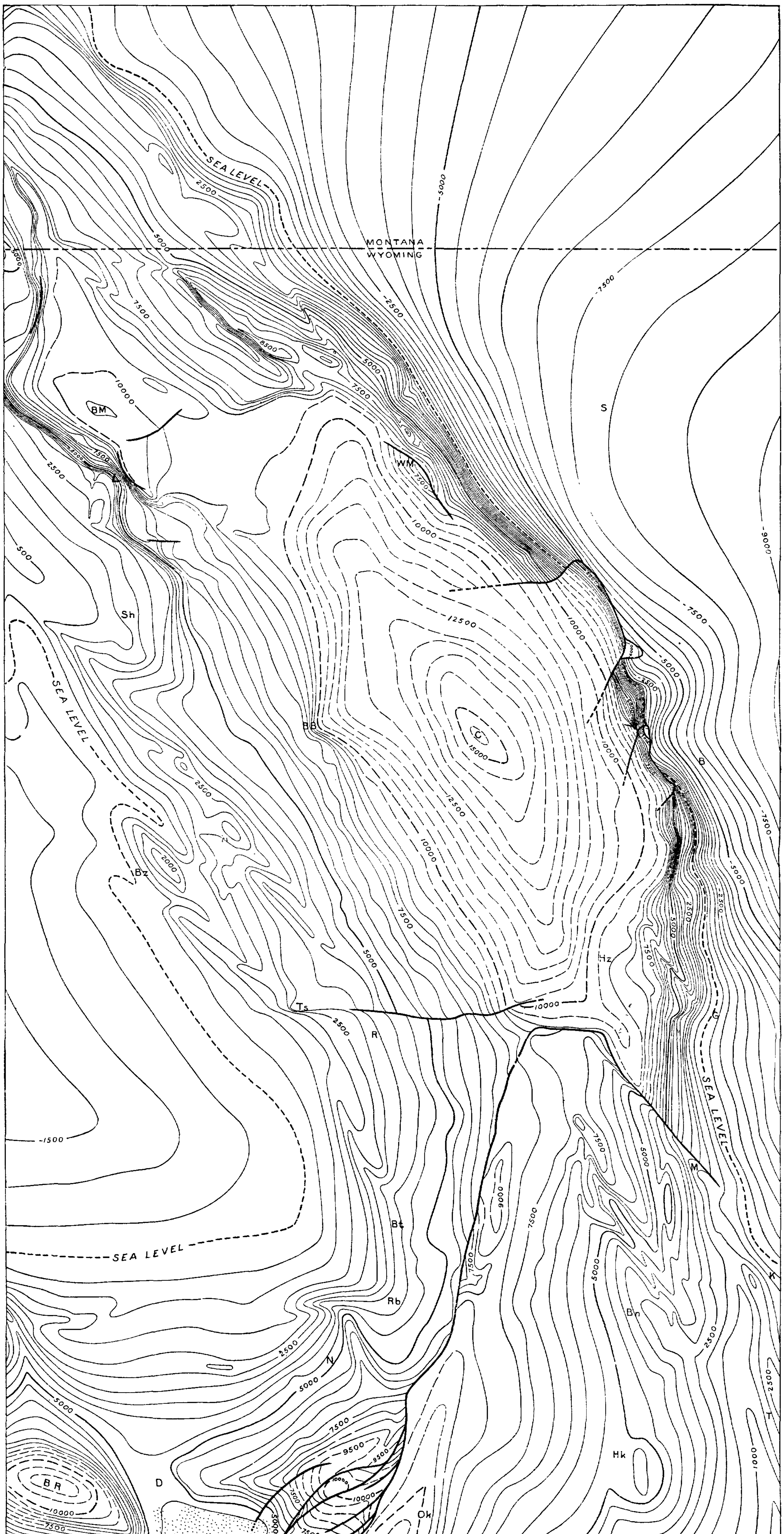


DIAGRAM OF BIGHORN UPLIFT REPRESENTED BY CONTOURS AT THE BASE OF THE MADISON LIMESTONE.

Contour interval, 500 feet.

C, Cloud Peak; S, Sheridan; B, Buffalo; L, Walker Mountain; BM, Bald Mountain; Sh, Shell; Bz, Bonanza; H, Hyattville; W, Black Mountain; Hz, Hazelton; G, Greub; T, Tensleep; Bt, Bigtrails; M, Mayoworth; Kc, Kaycee; Bm, Barnum; Ts, Tisdel's; H, Houck's; Ok, Okie's Store; LC, Lost Cabin; D, Deranch; N, No Wood; Rb, Redbank; BR, Bridger Range.

trends first north-northeast and then northeast, finally passing out under the Kingsbury conglomerate. A branch fault extends a short distance to the northwest in such manner that the granites advance considerably to the east in a prominent eminence, with Tensleep sandstone and possibly Chugwater red beds also in contact with the granite. Another fault develops north of South Fork of Rock Creek and trending north-northeast crosses all the formations from Cambrian to Piney. On the divide north of North Fork of Rock Creek it turns eastward and describes a loop which extends under the Kingsbury conglomerate that here is in contact with Bighorn limestone and the Deadwood formation. A small branch fault continues northward and brings the Cambrian shales and Madison limestone into contact along the foot of the limestone front ridge, which here begins again, having been cut out by the main fault in the slopes adjoining North Fork of Rock Creek. These faults in their maximum development have from 5,000 to 9,000 feet throw, with the drop on the east side. Doubtless some of them extend far to the southwest into the crystalline-rock area, but they could not be traced in that direction.

In the region west of Kearney the limestone front ridge presents steep dips and the strike is nearly straight, trending north-northwest. The great fault which begins in the granite a short distance north of section 6 (see Pl. XXXVIII) passes along its eastern side. Here the Kingsbury conglomerate is in contact with the Madison limestone, as shown in Pl. XIX, *B*, except for a short distance south of North Piney Creek, where the Amsden and Tensleep formations appear. The relations between overlap and faulting along this line could not be determined. Presumably there has been both early Laramie and post-Laramie movement along the fault. At the northwest end of Moncrief Ridge this fault must merge into the great cross fault which extends on a northeast course along the south side of Little Goose Creek Valley, but owing to the overlap of Kingsbury conglomerate and heavy talus from the slopes the relations of the two could not be determined.

REGION WEST OF SHERIDAN.

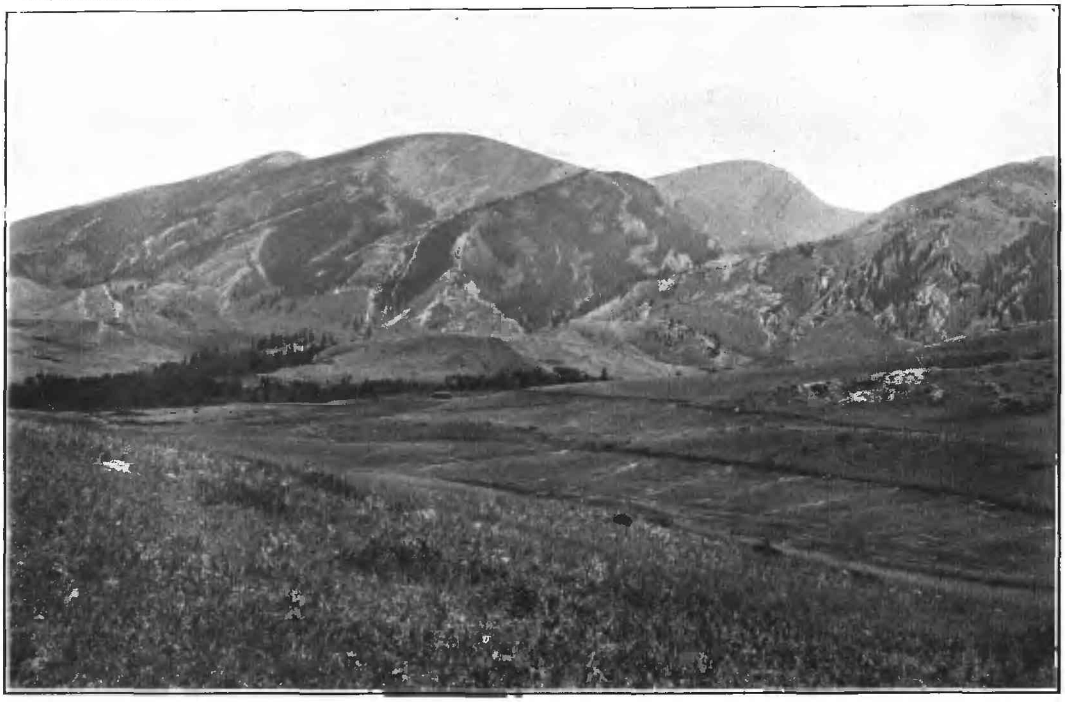
The structure of the northeast portion of the Bighorn Mountains presents four general features: (1) The broad area of low northeasterly dips in the plains east of the mountains; (2) the rise of the beds with rapidly increasing dip on the flanks of the Bighorn uplift; (3) the broad anticlinal summit of the Bighorn uplift, pitching to the northwest and denuded of sedimentary rocks in the granite region to the south, and (4) the margin of the westward-dipping strata on the west side of the uplift. It is probable that the sedimentary rocks originally arched over the central area and had moderate dips in this district. The principal structural features of the district are shown in the eastern sides of sections 3 and 4, Pl. XXXVIII.

In the wide area underlain by the De Smet formation in the district east of the mountains the strata have a low general dip northeastward, with a few local variations. In the vicinity of Ranchester and eastward the dips are from 3° to 4°. In the outcrop zone of the Piney formation the dips vary from 10° in the vicinity of Parkman to 50° or more on Little Goose Creek, the steepness gradually increasing from north to south.

In the zone of Parkman sandstone exposures west of Parkman the dip averages 10°; near Dayton it is increased to 20°, which it preserves as far south as

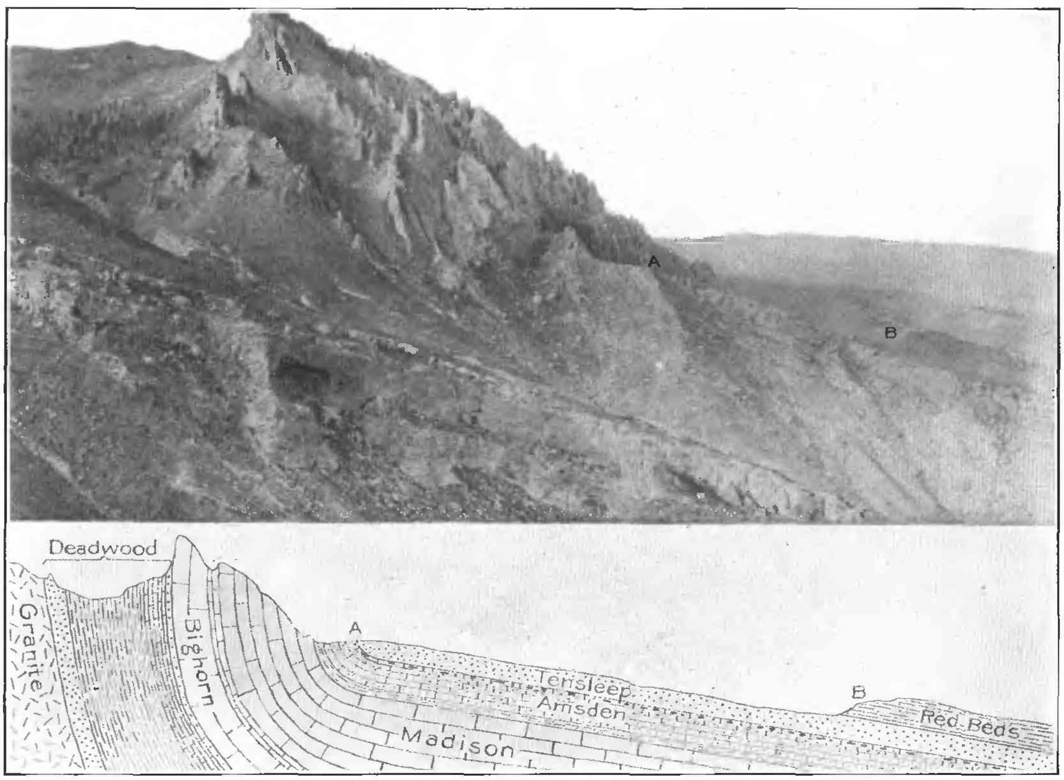
Beaver Creek, with small local variations; southward it increases rapidly, and approaches the vertical from Jackson Creek to the fault which cuts off the sedimentary beds southeast of Goose Creek. In general the dips increase materially between the Parkman sandstone outcrops and the foot of the mountains, especially to the south. The Chugwater red beds have dips averaging 13° on Twin Creek, 18° on Columbus Creek, 20° on Amsden Creek, 40° on Tongue River, 36° on Wolf Creek, 40° on Soldier Creek, 38° on Big Goose Creek, and are nearly vertical from Jackson Creek to beyond Little Goose Creek. These are also the average dips of the steep rise of the strata in the front range on the east side of the Bighorn uplift in this district, except that their amount diminishes considerably along the west side of the front range. In general the front range presents a fine example of moderately steep monoclinal structure, with but slight variation in the line of northwest-southeast strike. On Columbus Creek a gentle anticline with corresponding syncline develops high on the slope of the monocline. These trend north-northwestward and pitch rapidly toward East Pass Creek. The anticline gives rise to a high ridge of Madison and overlying beds on the east side of this creek, and the creek valley follows the syncline for some distance in Chugwater, Tensleep, Amsden, and Madison beds. In the axis of the anticline, on Columbus Creek, a small area of Bighorn limestone is revealed at the bottom of the canyon. Near the mouth of Tongue River Canyon there is a prominent eastward bulge of the front-range strata. A small syncline and anticline in the Chugwater and Sundance formations on Smith Creek, and a small flexure of similar shape in the limestones and sandstones on the mountain slope along and near the main road east of Little Goose Creek, are other irregularities in the general monocline. From Little Tongue River to a point south of Soldier Creek there are a sharp anticline and syncline in the monocline, which are well exhibited in Elephant Foot and on Wolf Creek (see Pl. XXXIX, *A*). This anticline is faulted at one or two points, notably on Soldier Creek and in the slopes on the southeast side of Wolf Creek, as shown in Pl. XL, *A*. At the latter place the dislocation is about 400 feet, with the upthrow on the east side.

Another smaller fault is seen in the Deadwood formation south of Rapid Creek. To the southeast, near Little Goose Creek, the entire monocline is cut off by a profound fault trending northeast and bringing the crystalline rocks far above their former position. It has nearly 10,000 of vertical displacement. In Walker Mountain, between Wolf Creek and Big Goose Creek, the Deadwood formation and the Bighorn and Madison limestones occur in an outlying area due to a fault. The faulted block is tilted at a moderate angle to the northeast, in which direction the fault increases in throw. The general structure is synclinal, with the eastern limb cut off by the fault, except at its south end, where, in the slopes on the north side of Big Goose Valley, the Deadwood beds exhibit the syncline and anticline, the latter connected with the main front range. North of Tongue River the sedimentary beds arch over the granites in a pair of low anticlines pitching to the northwest. One of these develops into the Pass Creek anticline north of Freeze Out Point, and extends to the red beds on East Pass Creek, on which it exhibits a low arch in the Tensleep sandstone. The other anticline passes up the south side of Sheep Creek Valley and merges into the great anticline of Dry Fork Ridge. The intervening syncline is exhibited by westerly dips in Bighorn limestone on the west slope of



A. EAST SLOPE OF THE LIMESTONE FRONT RIDGE OF THE BIGHORN MOUNTAINS.

Twenty miles west-northwest of Sheridan, Wyo.; looking west-southwest. Shows eastern dip, with a local syncline to right of center in distance; higher ridges due to Madison limestone; Tensleep sandstones on the slopes, ending in valley of Chugwater Red Beds in middle-ground.



B. AMSDEN AND ASSOCIATED FORMATIONS IN SHARP UPTURN ON EAST SIDE OF LIMESTONE FRONT RIDGE OF BIGHORN MOUNTAINS.

North side of North Fork of Crazy Woman Creek, west of Klondike, Wyo.; looking north. Crest and higher slopes to left are Bighorn and Madison limestones; the latter also descends canyon at base of view; thin-bedded strata are Amsden formation.

Freeze Out Point and easterly dips in Deadwood and Bighorn beds along Sheep Creek. The syncline to the west holds a thick mass of Madison limestone in the prominent ridge west of Sheep Creek. It pitches to the northwest.

MONTANA REGION.

The structure of the northern portion of the Bighorn uplift has been determined only east of the vicinity of longitude 108°. North of the Montana line the anticline is greatly narrowed, relatively simple in contour, and pitches down to the north-northwest. Section 1, Pl. XXXVIII, shows its salient features. There is a long monocline of gentle dips on the east side, and on the west an alternation of step-like folds consisting of narrow zones of steep dips with wide intervening areas in which the strata are nearly horizontal or pitch gently northwestward. The highest of these steps passes near Lookout Point, a short distance west of which the granites appear in a sharp upturn which to the north of the line of cross section develops into a fault, bringing the Deadwood and Madison beds into contact. West of this fault and flexure the beds dip very gently to the northwest, and the Tensleep and Amsden formations constitute a wide plateau along the general mountain slope. In the monocline on the east side of the uplift, in Montana, there are a few minor crenulations, the most marked of which crosses Lodge Grass Creek as a syncline, which holds the Sundance formation to the south and the Sundance and Morrison formations to the north of the creek. Toward the canyon of Bighorn River the beds on the east side of the mountain pitch down steeply in a narrow zone, but higher on the arch the dips are greatly diminished and the principal feature is the pitch to the northwest. Black Canyon cuts deeply into the higher portion of the uplift, exposing a wide area of Deadwood beds a short distance north of section 1. At the canyon of Bighorn River the flexure is greatly diminished in altitude. The stream has cut a deep canyon, exposing the limestones as shown in Pl. XV (p. 32), with the summit ridges capped by Amsden beds.

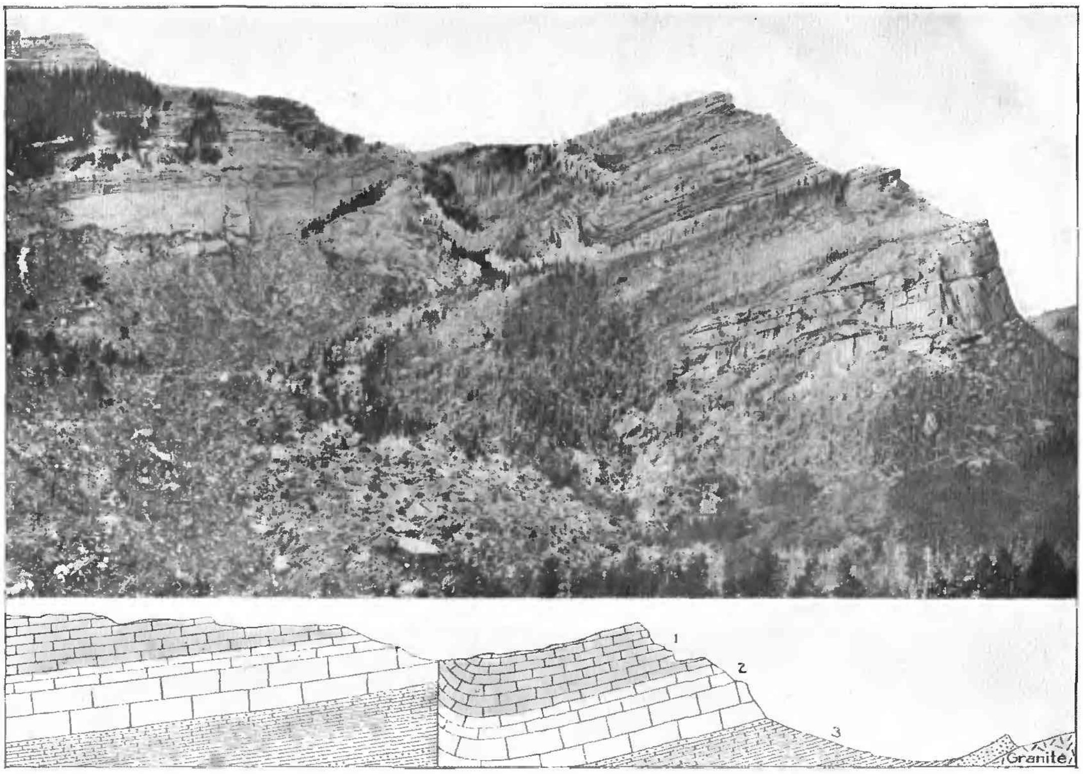
At the lower end of the canyon the beds on the east side of the uplift dip steeply, the entire succession from Madison limestone to lower Benton shales disappearing beneath the surface in a zone half a mile wide. Some features in this locality are shown in Pl. XV. A short distance north of the Bighorn River the formations from Chugwater to Benton pass around the northern end of the uplift, but they rise again farther to the northwest on the flanks of Pryor Mountains, which are in part due to the local increased elevation along a continuation of the western side of the Bighorn uplift.

BALD MOUNTAIN REGION.

The salient features of the northwestern portion of the region are the steep rise of the beds on the western side of the uplift and the great breadth and flatness of its summit. The most elevated portion of the uplift lies near the top of the mountains, but for a breadth of 10 miles the top of the arch is nearly flat, and it has but little pitch to the north and southeast. The beds rise toward Bald Mountain in a low dome, while in the region on either side of Tongue River, especially to the south, they lie nearly level for many square miles.

On the eastern limb of the general uplift, east of Bald Mountain, rises a very prominent anticline, which raises the beds about 2,500 feet for some distances, mainly in Dry Ford Ridge. It strikes northwest-southeast, and its higher portion has a length of 15 miles from West Fork of Little Bighorn River to Tongue River. Its top is nearly level for this distance, and it pitches down gradually at each end. On the west side the dips are nearly vertical for the greater part of its course, and on the east side they are about 12°. This anticline is finely exposed on Little Bighorn River which crosses it in a canyon with walls over 2,500 feet high. The granite is exposed for nearly a mile in this canyon, which cuts into it nearly 500 feet in the center of the uplift. Long slopes of Deadwood shales surmounting the great cliffs of granite extend to limestone walls in which the entire thickness of Bighorn and Madison limestones is exhibited. In Pl. XLI are shown the principal features of this great exposure. To the north of Little Bighorn River the flexure rapidly pitches down, but it is tractable with diminished height across West Fork and thence northwesterly across Lodge Grass Creek. In the canyons of these two creeks the flexure is exhibited in upper Deadwood beds and the Bighorn and Madison limestones. South of Little Bighorn Canyon the anticline forms the high Dry Fork Ridge which is capped by Madison limestone dipping gently northeastward under a regular succession of beds of which the Amsden extends far up the local divides. The underlying Bighorn limestone also appears along the crest of this ridge in high cliffs facing southwestward and surmounting slopes of Deadwood limestones and shales in which the crest of the anticline lies. These limestones and shales are extensively bared by West Pass Creek, and they pitch beneath the Bighorn limestones to the southeast.

West of the anticline is a syncline holding Amsden, Tensleep, and Chugwater beds in a shelf extending along the east side of Dry Fork Valley. The western limb of this syncline is a long, gentle monocline which continues to the crest of the main uplift. On this monocline are long slopes of Madison limestone (overlain at first by Amsden beds on the divides), Bighorn limestone, and Deadwood beds. Lodge Grass Creek, Little Bighorn, and Tongue rivers, and branches of Dry Fork cut deeply into this slope, all but the former revealing the granite in parts of their courses. Little Bighorn River has a notably deep canyon above the mouth of Dry Fork cut into the Deadwood beds and having high walls of Bighorn and Madison limestones. Tongue River has cut a wide valley, in part with granite floor and with extensive slopes of Deadwood beds. On the top of the Bighorn uplift in the upper Tongue River region the beds lie nearly level, except toward Bald Mountain, where a low dome rises. The pitch is such that the beds are about 500 feet higher on the headwaters of Little Bighorn River than in the divide south of Tongue River. Accordingly, as the elevation of the higher lands is relatively uniform, that divide is capped extensively by Madison limestone which extends nearly to Little Bald Mountain, while in the region about Bald Mountain Deadwood shales and sandstones and granite occupy most of the surface. The higher summits, from Duncom Mountain northward and north of Little Bald Mountain, are capped by irregular areas of Bighorn limestone. The dome which culminates in Bald Mountain rises about 600 or 700 feet above the level of the wide, flat top of the Bighorn uplift. It is elongated to the northwest and south, having a curved strike. To the south it



A. FAULT ON THE SOUTH SIDE OF WOLF CREEK CANYON.

Displacement amounts to about 400 feet and is in middle of view; Bighorn limestone in cliff to right and again prominently several hundred feet higher to the left; above are Madison limestones. Looking south.

B. FAULT ON TRAPPER CREEK.

Six miles north of Black Butte, Bighorn Mountains, Wyo. Upturned Deadwood beds to left; Bighorn limestone to right.

narrows gradually in Hunt Mountain, and, as it pitches down on the headwaters of the east branches of Red Gulch, it becomes a steep-sided anticline. This is well exhibited in Bighorn and Madison limestones where they arch over it at the eastern termination of the outcrop of Deadwood formation. The flexure is traceable for several miles eastward in Madison limestone on the plateau, and where it crosses Cedar Creek, at the forks of that stream, a small area of granite is revealed in its axis. East of this point it extends up Cedar Creek Canyon, becoming very low in the divide at the head of that stream.

In the region bordering Shell Creek Canyon the beds on the slope of the uplift dip gently to the west for a long distance, with a noticeable increase of steepness near the mouth of White Creek Canyon. This steepening along the western slope increases to the north, giving rise to dips of 20° at the mouth of Shell Creek and of 50° or more on Horse Creek and northward. These steep dips are in a narrow zone along the mountain front and affect mainly the Amsden, Madison, and underlying formations. This feature of a zone of steep dips interrupting a general gentle slope of the strata is a characteristic one along the western slope of the Bighorn uplift. On South Beaver Creek two of these zones coalesce, and there is local overthrust and fracture. Northwest from this locality the western side of the uplift has moderately gentle dips near the crest, very steep dips in a zone about a mile wide in which the strata from Colorado to Deadwood are nearly vertical, and then a wide area of very gentle westerly dips extending out under the Bighorn Basin, giving rise to broad outcrops of the Colorado and associated formations.

North of Willow Creek the average strike is nearly north-south, and the general westerly slope of the main Bighorn uplift is interrupted by two zones of steep dips, with intervening zones of nearly horizontal beds forming huge steps or plateaus in the mountain slopes. The Chugwater, Tensleep, and Amsden beds on these steps are deeply trenched by Devil Canyon and Deer and Trout creeks, the first cut through into the Bighorn limestone. From the upper one of these plateaus the strata rise steeply, partly aided by a fault extending from Devil Canyon to Cookstove Basin. In this rise the granites appear extensively, capped to the east by Deadwood sandstone, shales, and limestone, and the overlying Bighorn limestone on the gently rounded crest of the central axis of the main uplift. In the vicinity of Sheep Mountain the crest of the flexure is flat, but of much less width than in the region south, and this narrowed anticline continues far to the north with but slight diminution in altitude. There is a sharp local flexure on the east side of this anticline, exhibited in a Bighorn limestone cliff on the east side of Lodge Grass Creek, southeast of Sheep Mountain. It is traceable to the head of West Fork, beyond which it dies out. Another similar anticline develops in the valley of Little Bighorn River, 6 miles northeast of Bald Mountain, and extends southeast across the next divide. It lifts the granite floor so high that it is revealed by erosion in the Little Bighorn Valley and again in the next depression south. In the canyon of North Beaver Creek there is a small local twist in the strata, shown in the Madison limestone and Amsden beds, as illustrated in Pl. XLI. It consists of a shallow syncline, which soon disappears in the limestone slopes to the north, and an anticline, which extends down Beaver Valley to Cloverly and then trending east finally broadens out and is lost in Red Gulch. It exhibits the Sundance formation along nearly all its course. Northeast of Cloverly it develops into a fault for a short distance.

The strata are broken by but few faults in the Bald Mountain area. The principal dislocation extends northward along the western slope of the mountain from south of Devil Canyon to beyond Deer Creek. The strata are dropped on the west side and apparently its hade is vertical. The fault develops rapidly in the steeply dipping strata, and along the greater part of its course the middle beds of the Madison limestone abut against the granite. On the north side of Devil Canyon, near the line of section 2, Pl. XXXVIII, the throw is over 1,200 feet, an amount which continues to Deer Creek, beyond which the fault rapidly diminishes and gives place to flexure. Along the fault the limestone is shattered and upturned.

On South Beaver Creek there is an overthrust fault along the west side of the mountain, amounting to about 1,500 feet, in which the granite has been pushed up over the middle beds of the Madison limestone. The hade dips about 50° to the northeast or upthrow, and the granite-limestone contact is clearly exposed for several yards on the south side of the creek. The relations exposed are shown in fig. 12. This fault has a length of about 2 miles, dying out rapidly in each direction. On the divide south of the mouth of the canyon of South Beaver Creek there is a short ridge of Madison limestone lying one-fourth mile west of the fault above described. It rises out of a terrace of bowlders which so covers the ridge that the structural relations could not be determined. It is in line with Chugwater outcrops not far away, on each side, but undoubtedly is brought up by a local fault, possibly a branch of the main one. A fault of small amount crosses Horse Creek Canyon a short distance above its mouth, and is exhibited in Bighorn, Madison, and Amsden beds. It was traced for about 2 miles along a nearly east and west course and found to have downthrow on the south side.

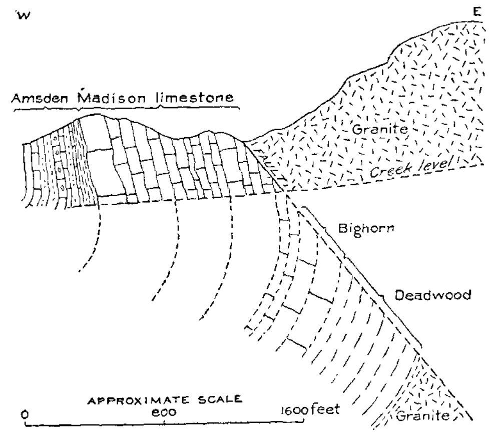
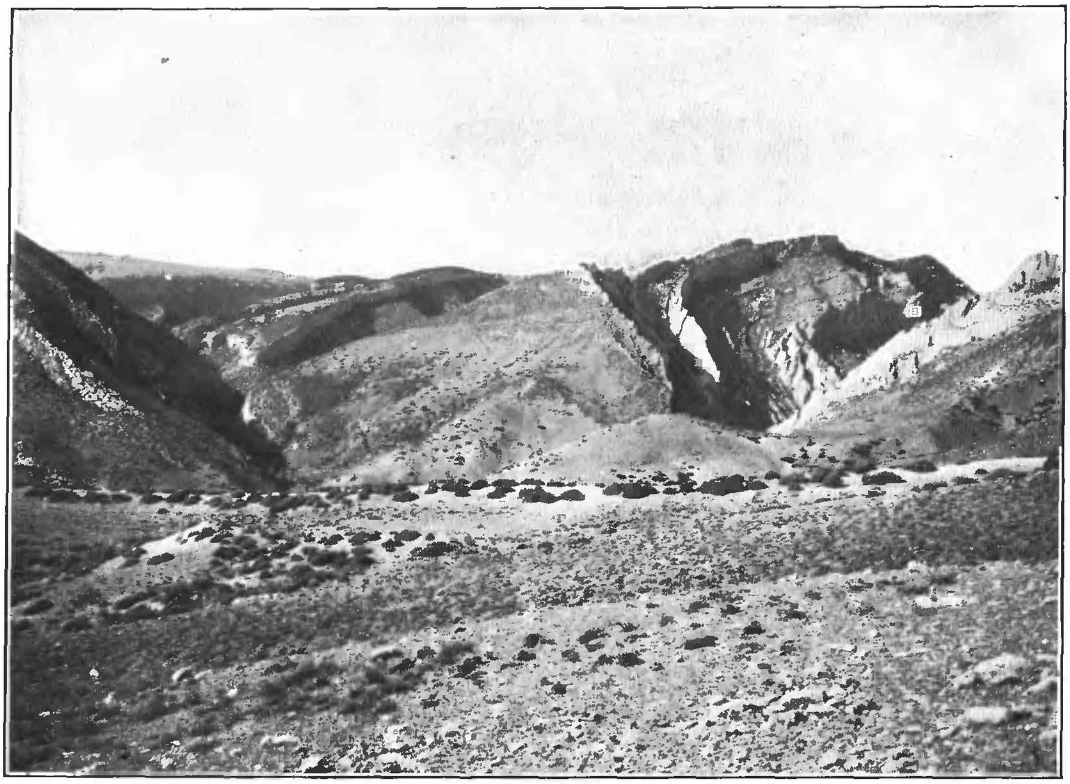


FIG. 12.—Section at fault on South Beaver Creek, looking north.

A fault crosses the crest of the Bighorn axis east and south of Little Bald Mountain, with a length of about 4 miles and a general northeasterly course. It is exhibited in Deadwood, Bighorn, and Madison beds, which are downthrown on the south side. It amounts to about 400 feet at the greatest—on the divide north of the head of Tongue River. Here the Madison limestone abuts against the Bighorn and Deadwood beds.

The narrow anticline which extends down the valley of North Beaver Creek develops into a fault for some distance northeast of Cloverly and brings up the middle Sundance beds against the lower portion of the Morrison.

In the northwestern portion of the area the west slope of the Bighorn uplift descends into a syncline which extends north from the vicinity of Shell Creek. To



A. FLEXURES ON WEST SLOPE OF BIGHORN UPLIFT, ON NORTH BEAVER CREEK.

Four miles north of Cloverly, Wyo.; looking northwest. To right are Bighorn and Madison limestones and overlying beds dipping steeply west; to left of middle is a shallow syncline in Red Beds; to extreme left are steep westerly dips again

B. ANTICLINE ON EAST SLOPE OF BIGHORN UPLIFT.

North side of canyon of Little Bighorn River. Granite to right overlain by Deadwood formations, Bighorn and Madison limestones; knob to right and park to left are Amsden formation. B=Bighorn limestone.

the west in the Bighorn Basin rises the prominent anticline of the Sheep Mountain uplift. The syncline is shallow, having gentle dips on its sides, but it is sufficiently deep to hold over 1,000 feet of Colorado shales. Its deepest portion is a few miles northwest of Shell, where the highest ridges are capped by beds believed to be of Niobrara age. South of Shell Creek this syncline rises rapidly, bringing up Cloverly, Morrison, Sundance, and Chugwater beds, and bifurcates around a sharp anticline which is finely exhibited on Shell Creek near Sheldon's ranch by an arch of the Cloverly and Morrison formations. This flexure rises to the southeast and, together with the eastern syncline, finally merges into the main Bighorn monocline northeast of Hyattville. West of Sheldon's ranch there is a syncline in Colorado beds, west of which rises the southern part of the Sheep Mountain anticline. The syncline widens and deepens to the south and in the region east of Basin holds a broad area of nearly level Pierre shales.

SHEEP MOUNTAIN UPLIFT.

The Sheep Mountain uplift is an anticline rising in the east side of the Bighorn Basin and trending northwest-southeast, parallel to the main Bighorn uplift for 40 miles or more. It appears in Pierre shales at Basin and gradually rises until at the ridge known as Sheep Mountain the Madison limestone is exposed. At this place it is crossed by Bighorn River in a deep gorge. To the north the flexure broadens into a compound anticline with various subordinate flexures. In this area there is a broad valley of Chugwater red beds along Bighorn River, with low dips in various directions. East of the river are ridges of Sundance and Cloverly formations spread out widely by low dips. In the northern portion of township 55 there is a slight rise of the beds from the south over a low arch with steeper dips to the northeast on its northeast side. Bighorn River crosses this arch in a shallow gorge, exposing the top of the Madison limestone. North of this gorge there is the wide syncline above described, which extends to the base of the Bighorn uplift. It holds several hundred feet of Colorado shales near Kane.

WEST SLOPE FROM SHELL CREEK TO TENSLEEP CANYON.

Along the south side of Shell Creek Canyon, the great limestone escarpment trends east and southeast for 14 miles, south of which there are long slopes of Madison limestones and Amsden beds, with spurs and outliers of Tensleep sandstone. These descend in a broad, irregular syncline of which the principal relations are shown in section 5, Pl. XXXVIII.

South from a point opposite the mouth of Willitt Creek the limestone escarpment turns south and its trend is almost straight in that direction to Black Butte, where it makes an abrupt turn to the southeast. The prominence of this butte is due to the change in strike and the sudden local increase of dip in the Bighorn and overlying limestones. Along the mountain slopes in the region south of Black Butte the general dip is to the west and west-southwest at angles mostly from 9° to 12°. There are local variations in strike along the mountain slopes, especially in the Amsden and Tensleep beds north of North Fork of Brokenback Creek, but their effects are small. In the area of the Chugwater red beds the dips are all very low and, beginning on the divide between South Fork of Brokenback Creek and Tensleep Creek, a low anticline extends northwest for many miles, crossing Paintrock Creek a short distance west of Hyattville. It is plainly exhibited in Tensleep sandstone, in the two forks and north branch of Brokenback Creek, and in the high ridge of lower Chugwater red beds to the north. In this ridge small canyons cut through the red shales and expose the top of the Tensleep sandstone. West of Hyattville the anticline presents an eroded arch of Cloverly sandstone and the greater part of the Morrison formation, while on either side are ridges of the hard beds in the Colorado formation.

WEST SLOPE FROM TENSLEEP CREEK TO HEAD OF NO WOOD CREEK.

South of Tensleep Canyon there is a general deflection in the strike of the sedimentary rocks to the southeast, partly due to flexure and partly to extensive faulting. The structural relations are shown in Pl. XXXVIII and the character of one of the faults is there represented in section 8. This fault is a strongly marked feature along the north side of Canyon Creek Valley north and northeast of Rome. In its greatest development, which is north of Rome, its vertical displacement of 700 feet brings upturned Tensleep sandstone beds into contact with Madison limestone, the latter rising in a cliff capped by Amsden and Tensleep beds. This cliff extends eastward for about 7 miles, from a point 4 miles east of Tensleep, and the fault gradually diminishes, so that where it crosses Canyon Creek Canyon, at the big bend in the creek, it is entirely in Madison limestone and has a throw of about 400 feet. To the east of this point its throw increases somewhat, and it is exhibited by Madison and Bighorn limestones and the Deadwood formation, the latter being entirely cut out for a short distance where the Bighorn limestone and granite are in contact. It passes entirely into the granite on the main divide, and it could be traced no farther. One of the best exposures of the dislocation is at the place where Canyon Creek crosses the fault northwest of Rome and enters a deep canyon of Madison limestone. South of the entrance of this canyon is a wide valley of Chugwater red shales and this rock and some ledges of underlying Tensleep sandstone are steeply upturned against the fault. Here the amount of displacement is about 400 feet. West of the entrance of this canyon the throw diminishes rapidly and at one point near by the upturned Chugwater red shales are in contact with Amsden red shale. At a point 4 miles east of Tensleep the fault merges into a flexure which then extends west for some distance. This flexure is marked by a narrow zone of steep southerly dips, which first appear in a ridge of Chugwater red shales, extending along the south side of Tensleep Valley just south of Tensleep. This zone crosses No Wood Creek just above the mouth of Tensleep Creek, forming a narrow ridge of steep, southward-dipping beds from upper Chugwater to lower Colorado, which extends to the western margin of the quadrangle. The dips are nearly vertical for a few hundred yards, but give place abruptly to nearly horizontal beds to the north and south.

South of this displacement the west slope of the uplift presents very low, uniform dips, and the Chugwater red beds extend eastward far up the flanks of the mountain, in some places abutting against the fault described on page 103. The larger creeks cut through the red shales into the Tensleep sandstone. Numerous deep canyons are thus formed, especially on the two branches of Otter Creek and on Little Canyon Creek. North of Bigtrails a small anticline develops on the western slope and extends north-northwestward, finally pitching down near Kimball Draw. It appears first in the Chugwater red beds, but as the pitch diminishes to the north the various formations from Sundance to Colorado pass over the arch. Some of the small creeks cutting through from the west expose inlying areas of the Morrison and Sundance formations. To the east is a syncline holding several hundred feet of Colorado shale, and to the west is a shallow monocline containing Pierre shale and overlying formations, which extends far to the northwest into the Bighorn Basin. Near Redbank the strike turns rapidly to the west, owing to a prominent anticline which develops in the mountain slopes east of No Wood and extends northwestward. In these slopes this is marked by a high ridge, mostly of Tensleep sandstone. Some of the relations in this vicinity are shown in section 10, Pl. XXXVIII. No Wood Creek crosses this ridge in a canyon having walls nearly 1,000 feet high, exhibiting a splendid arch of Tensleep, Amsden, and Madison formations. The dips on the sides are steep, the Tensleep sandstone passing under the Chugwater red shales on either side of the gap. This sandstone also pitches under the red beds a short distance to the north. In the vicinity of No Wood there is a general monoclinal dip to the northwest, extending continuously from the mountain summits 10 miles south of No Wood far out into the Bighorn Basin northwestward and exhibiting a complete succession of beds from granite upward. No Wood Creek flows in a valley of Chugwater red beds, but at one or two points small local anticlines have raised the Tensleep and Embar formations, into which the creek cuts short, deep canyons. On the west side of the valley there is a high "red wall" surmounted by slopes of Sundance and Morrison shales capped by cliffs of Cloverly sandstone, with highlands of Mowry shales a short distance back. The Chugwater red beds extend far up the slopes to the east, giving place to long slopes of the Tensleep and underlying formations.

REGION ADJOINING NORTH AND RED FORKS OF POWDER RIVER.

Northwest of Mayoworth the North Fork of Powder River follows for some distance a synclinal valley, on the east of which is a profound fault. To the east of this displacement is a high ridge, "The Horn," presenting an eastward-dipping, monoclinal succession from granite to the Colorado formation, which has been uplifted about 3,500 feet near the south line of township 46. In this vicinity the granite is brought up into contact with Chugwater red beds. In its northward extension the fault diminishes rapidly in amount and locally gives place to a syncline with very steep dips on its eastern limb. This is near latitude 44°, where the section is complete, but along the steep uplift there is considerable crushing. A short distance farther north the fault begins again, and in 2 miles the Tensleep sandstone is brought in contact with the granite. Approaching Powder River the fault trends nearly due west and amounts to 1,500 feet. After crossing that stream it turns to the southwest and rapidly diminishes in amount, so that on the summit of the mountain at the head of Pass Creek it is not perceptible, although a short distance south there develops in line with it a great fault, which extends thence southward for many miles. The small area lying between the terminations of these two faults has been a hinge, on which a great block constituting the southern end of the Bighorn uplift has rotated slightly, so that its eastern margin has dropped by the fault near the Horn and its western edge has been lifted by the fault extending many miles southward from the region near the head of Pass Creek. Owing to the dropping of the northern end of the block near Powder River, the Tensleep, Amsden, and Madison formations here arch over the summit of the main Bighorn uplift. On the crest of the arch they lie nearly level, but on the east side the strata descend gently into the shallow syncline along Powder River Valley north of Mayoworth. In the vicinity of section 9 an anticline develops on the monocline of the mountain slope, which extends far southward along the east side of the Red Fork of Powder River. Near its northern end this anticline exhibits a small area of the Deadwood and Bighorn formations, dipping steeply to the west on the west side and gently to the east on the east side of the arch. It widens to the south and causes a broad ridge, which at first exhibits Madison limestone in its center, but to the south consists entirely of Amsden and Tensleep sandstones. Below Brock's ranch the Red Fork flows along the crest of the anticline in Chugwater red beds, which extend nearly to Middle Fork, a short distance south of which the anticline dies out. A few miles south of Mayoworth a small subordinate anticline rises on the east side of the main one, causing a short but prominent ridge of Tensleep sandstone completely surrounded by red beds. Near Fraker's ranch on Red Fork another sharp but small anticline appears on the west slope of the main anticline, but its influence is of limited extent. It is most prominent in a high ridge of Tensleep sandstone, to which it gives rise, just north of Fraker's ranch. Red Fork cuts a deep canyon through the eastern end of it 2 miles east of that ranch. West of the main anticline there is a syncline which in the high ridges east of Barnum holds various formations up to the Mowry beds. Barnum is in a valley of red shales, west of which there is a long monoclinal slope of Tensleep and underlying formations rising to the crest of the Bighorn Mountains.

EAST SLOPE ADJOINING BUFFALO CREEK.

For the greater part of its course Buffalo Creek flows in the Red Valley skirting the southeastern side of the Bighorn Mountains. To the west are long slopes of eastward-dipping strata, beginning with the Tensleep sandstone on the lower and middle slopes and culminating in a series of high ridges and knobs of Madison limestone. West of this are narrow plateaus and slopes of the Deadwood formation constituting the summit of the main divide. The dips are rarely as much as 5°, and they are lowest in the vicinity of the line of an east-west section passing through the Hole-in-the-wall. From the last-mentioned place to Houck's, Buffalo Creek cuts a deep canyon in the Tensleep sandstone. At Houck's this formation presents a low anticline, which, with several undulations, extends for some distance east of the Buffalo Creek Valley, spreading the Chugwater red beds widely east of Houck's. A prominent feature in this uplift is a low dome about 2 miles east of Houck's, having steep dips on its western side and exhibiting the Tensleep sandstone for a short distance. On the eastern side of Buffalo Creek Valley south of Houck's and from the Hole-in-the-wall district northward a high wall of red sandstone of the Chugwater formation faces westward. East of this wall there are long slopes of formations from Sundance to Pierre to the south and to the north a shallow syncline, which crosses the West Fork of Powder River east of Barnum. The low anticline which is exhibited in the Tensleep sandstone at Houck's continues southwestward up Buffalo Creek Valley and is plainly exhibited, passing into the red wall and upper red beds at a point 7 miles southwest of Houck's.

CENTRAL RIDGE FROM OTTER CREEK TO OKIE'S.

As explained on a preceding page, a short distance south of latitude 44° the central axis of the Bighorn uplift gradually rises, mainly on account of the great fault which develops along its west side. This dislocation extends in an almost straight line from the head of the North Fork of Otter Creek south-southwest to the southern end of the Bighorn Mountains, the uplift varying from 500 to 1,500 feet and being on its eastern side. Its principal features are shown in sections 9 and 10, Pl. XXXVIII. On its western side appear Madison limestone, Amsden and Tensleep formations, and at a few points the Bighorn and Deadwood formations also. On the eastern side are extensive areas of the Deadwood formation, and in part of the area the underlying granite and schists. The latter outcrop in an area about 5 miles long at the head of branches of the Middle and South forks of Otter Creek and in a long area beginning near the head of the South Fork of Little Canyon Creek and extending southward to the southern end of the Bighorn uplift. The granite appears in the slopes west of the mountain crest, which consists of the basal sandstones of the Deadwood formation. This member varies in thickness from 250 to over 300 feet and lies nearly level in a plateau of moderate width constituting the summit of the main divide. East of this summit there are gentle slopes eastward into the valleys of various branches of Powder River and to the slopes of numerous high ridges of Madison limestone occupying the divides between these streams. The beds rise toward the south, and near Ballard & Fish's store the basal Deadwood sandstones reach an altitude of about 8,750 feet. Just west of the store the member caps a high mesa with slopes of granite, which are long and steep on the west side. The West Fork of Powder River heads in this vicinity and has cut entirely through the sedimentary rocks, so that its canyon is in granite as far as the middle of range 85. North, east, and south of Ballard & Fish's store are long sloping plateaus of the basal Deadwood sandstone, and this feature, narrowing somewhat to the south, extends to the vicinity of Okie's store. To the east are slopes of Deadwood shales surmounted by the Carboniferous limestone in knobs and ridges which rise somewhat above the level of the central divide.

SOUTHWESTERN TERMINATION.

Toward its southern termination the height of the Bighorn uplift increases, owing to a dome which reaches its maximum development a short distance southwest of Okie's store. On the southern side of this dome the strike changes at first to east-west and then to northwest-southeast, the sedimentary strata appearing on the slopes of the uplift in an irregular line of knobs and ridges descending to an irregular overlap of Tertiary deposits of the "Bridger" formation in the plains to the south. The great fault which follows near the mountain crest from the head of Otter Creek splits into an irregular series of small displacements, exhibited mostly in numerous outlying masses of Deadwood basal sandstones capping several high ridges about the heads of Deep, Lonetree, Badwater, Trout, Spring, and Sioux creeks. Some of these branch faults also extend southward into the overlying Carboniferous formations, as shown on the geologic map. West of the faulted area the axis of the uplift trends west and with gradual decrease in altitude finally pitches down into a low structural and topographic saddle at Deranch, as is shown on section 11. This portion of the uplift is narrow and in places so tightly pinched as to present dips of 25° and more. The last features of prominence at the end of the uplift are the ridges of Tensleep sandstone and Embar limestone dipping steeply to the west and southwest a short distance east of Bridger Creek. The saddle at Deranch consists of Chugwater red beds lying nearly level and overlain to the north by a thick mass of "Bridger" Tertiary deposits. A short distance south of Deranch Bridger Creek exposes a small local dome of Embar limestone and Tensleep sandstone, 2 miles south of which the Chugwater red beds pass under the "Bridger" Tertiary deposits. To the south these deposits cover the formations from Sundance to Pierre, which probably underlie the plains north of Lost Cabin.

BRIDGER RANGE.

The uplift to which this range is due rises immediately west of the saddle above described at the southwestern termination of the Bighorn uplift, and it is continued farther west in the Owl Creek Mountains. As shown on Pl. XXXVII, it is an anticline, with steep dips on its eastern and southern sides. In its central portion there is exhibited a large oval area of granites and schists rising in ridges of considerable prominence. These are flanked on the east and north by knobs and ridges of the Deadwood and overlying formations, which on the east side dip steeply and on the north side gently. To the north there is a prolongation of the uplift in an anticline which extends across the head of Buffalo Creek and finally merges into another east-west anticline which passes through Thermopolis. This east-west anticline brings Chugwater red beds to the surface in an area of considerable width north and east of Thermopolis. Between it and the Bridger uplift there is a syncline of moderate depth, containing several hundred feet of Colorado deposits. The relations along the south side of the Bridger uplift are not well exposed, owing to extensive overlap of the "Bridger" formation. This extends to the granites and schists in ranges 92 and 93, but in each of these ranges there is an outlying knob in which some of the Paleozoic rocks are exhibited dipping steeply to the south. In the one in range 93 the schists are seen to be separated from the Madison limestone by a fault. In range 94 the Bridger uplift pitches down somewhat to the west, and its southern side is seen to be extensively faulted. The faults and other structural relations are finely exhibited in the great canyon which crosses the uplift in range 6 east. In the center of this canyon, where its depth is over 2,000 feet, there is a complete exposure of all the beds below Embar limestone and deep into the granite and diorite schists. At the southern end of this canyon three faults are shown. The northern one has an upthrow of about 800 feet on its north side and brings up a mass of dioritic rock in steep black walls in the sides of the canyon. A short distance south there are two other faults in which a block is dropped a few hundred feet, so that the middle Deadwood beds are in contact with the upper portion of the granite.

UPLIFT NEAR TISDEL'S RANCH.

The uplift near Tisdel's ranch lies a short distance east of the area shown in the map (Pl. XLVII), and is mainly in R. 81, T. 41. It forms a ridge of considerable prominence lying east of the South Fork of Powder River east and southeast of Tisdel's ranch. It brings to the surface the sandstone at the top of the Colorado, and underlying formations down to the Sundance, the top of which is exposed in one of the small canyons 2 miles south of Tisdel's ranch. In this and adjoining canyons the Morrison formation is extensively exposed, and on the adjacent slopes the Cloverly sandstones appear in an area of moderate size. The Mowry beds extend along the slopes of the ridge for some distance, and the sandstone at the top of the Colorado formation extends northward nearly to Kaycee, in a nearly continuous prominent wall from 30 to 40 feet high.

LANDSLIDES.

On most of the slopes of the Deadwood formation there are extensive landslides often consisting of large masses of Bighorn limestone. They are due to the softness of the shales, which, when wet, can not sustain a heavy load. These slides are prominent features along both sides of the canyon of Little Bighorn River, where some of the masses are 1,000 feet long. Along Shell, Cedar, and Granite creeks they are frequent and large. Smaller ones occur on West Pass, Lodge Grass, and other creeks.

GEOLOGIC HISTORY.

GENERAL SEDIMENTARY RECORD.

The rocks uplifted in the Bighorn Mountains comprise granites of pre-Cambrian age, overlain by a thick series of sedimentary strata. The latter consists mainly of sandstones, limestones, shales, sand, loam, and gravels, all presenting more or less variety in composition and appearance. The principal materials of which they are composed were originally gravel, sand, or mud, derived from the waste of older rocks, or chemical precipitates from salty waters.

These rocks afford a record of physical geography from middle Cambrian time to the present. There has been considerable diversity of conditions, but an extensive stratigraphic record is presented. Some of the chapters of the history appear plain, but in others much additional study will be required before we can know the complete sequence of events. The composition, appearance, and relations of strata show in some measure the conditions under which they were deposited. Sandstones, ripple-marked by waters and cross-bedded by currents, and shales, cracked by drying on mud flats, are deposited in shallow water; pure limestones generally indicate open seas and scarcity of land-derived sediment. The fossils that the strata contain may belong to species known to inhabit waters which are fresh, brackish, or salt, warm or cold, muddy or clear. The character of the adjacent land may be shown by the nature of the sediments derived from its waste. The quartz sand and pebbles of coarse sandstones and conglomerates, such as are found in the Deadwood, Cloverly, and later formations, had their original source in crystalline rocks, but have been repeatedly redistributed by streams and concentrated by wave action on beaches. Red shales and sandstones, such as make up the red beds, usually result directly from the revival of erosion on a land surface long exposed to rock decay and oxidation, and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low, and that its streams were too sluggish to carry off coarse sediments, the sea receiving only fine sediment and substances in solution. The older formations exposed by the Bighorn uplift were laid down from seas which covered a large portion of the central-western United States, for many of the rocks are continuous over a vast area. The land surfaces were probably large islands of an archipelago, which was to some degree coextensive with the present Rocky Mountain province, but the peripheral shores are not even approximately determined for any one epoch, and the relations of land and sea varied greatly from time to time. Pursuing these general ideas more in detail, one finds that the strata brought to view by the Bighorn uplift record many local variations in the ancient geography and topography of the continent.

CAMBRIAN SUBMERGENCE.

One of the great events of early North American geologic history was the wide expansion of an interior sea over the western-central region. The submergence reached the Rocky Mountain province in middle Cambrian time, and for a while found an irregular shore line about a great series of archipelagoes. From the ancient crystalline rocks of these shores waves and streams gathered and concentrated sands and pebbles, which were deposited as a widespread sheet of sandstone and conglomerate on sea beaches, partly in shallow waters offshore and partly in estuaries. Numerous exposures are now found in which these sediments, containing much local material, may be seen abutting against the surface of the crystalline rocks which formed these shores. The central portions of the Bighorn Mountains and Black Hills may have been islands in the earlier stage of this period, and the Laramie Range and Rocky Mountain Front Range were highlands rising out of the Cambrian sea. After these earliest shore-line conditions the altitude was reduced by erosion and the area was possibly lessened by submergence. Some of the islands yielded the finer-grained muds now represented by the shales and limestones which occur in the upper portion of the Cambrian, but in many regions the land surface of crystalline rocks was buried beneath the sediments. The limestone conglomerates at the top of the Deadwood formation indicate recurrence of shallow-water conditions, the latter probably marking the beginning of emergence, which lasted through the later part of Cambrian and earlier part of Ordovician time. During this time the Bighorn area was part of a land area which extended north from the Laramie Range and the Rocky Mountains.

ORDOVICIAN SEA.

Early in Ordovician time there was submergence of the northern and central portion of the Bighorn Mountain area, in the earlier stages with deposition of sands and later, with increased submergence, with extensive deposition of lime carbonate, which continued during Trenton time. There was uplift in middle Ordovician time, followed at the end of the period by submergence, during which limestones representing the Richmond were deposited. This continued until the end of the Ordovician.

SILURIAN-DEVONIAN CONDITIONS.

From the close of Ordovician to early Carboniferous time the Bighorn Mountains present no geologic record, the Silurian and Devonian being absent. This is probably because there was an extensive but very shallow sea, or land so low as to leave no noticeable evidence of erosion. Whether it remained land or sea, or alternated from one to the other condition, the region shows no evidence of having undergone any considerable uplift or depression until early in Carboniferous time, when there was a decided subsidence that established relatively deep-water and marine conditions, not only over the Bighorn area, but generally throughout the northern Rocky Mountain province.

CARBONIFEROUS SEA.

Under the marine conditions of the early Carboniferous there were laid down calcareous sediments, which are now represented by nearly 1,000 feet of limestone, known as the Madison limestone. As no coarse deposits occur, it is possible that no crystalline rocks were exposed above water in this region, though in other regions to the south the limestone or its stratigraphic equivalents was deposited immediately upon them. Later in Carboniferous time the conditions changed and a sheet of red shale of wide extent was deposited, followed by alternations of pure limestones and sandy limestones, and local sand deposits several hundred feet thick constituting the Amsden formation. This deposition was followed by an uplift in which there were shallow waters and strong currents, which deposited a thin but extensive sheet of sand, known as the Tensleep sandstone. In the southern portion of the Bighorn area this condition gave place to deposition of clay and then of carbonate of lime, now represented by the Embar formation. Then followed a period of uplift culminating in the late Carboniferous or Permian time in a widespread lake of saline water in which the Chugwater formation accumulated. This great mass of red shales, with its extensive interbedded deposits of gypsum, presumably products of an arid climate, accumulated to a thickness of over a thousand feet in parts of the area. There is such uniformity of the deep-red tint that this is undoubtedly the original color. It is present not only over the entire outcrop of the formation but also throughout its thickness, as is shown by deep borings. It is, therefore, not due to later or surface oxidation. This deposition of red mud was interrupted from time to time by chemical precipitation of comparatively pure gypsum in beds ranging in thickness from a few inches to 30 feet and usually free from mechanical sediments. It is apparent that these beds are the products of evaporation while mechanical sedimentation was temporarily suspended, a condition indicative of greatly diminished rainfall; otherwise it is difficult to account for their nearly general purity. Most of the red deposits were laid down in shallow water, so that there must have been a subsidence which kept pace with deposition most of the time. At an early stage in the deposition of the red beds there was a widespread interruption in the shale sedimentation and a thin but wonderfully persistent bed of limestone was laid down. It is only a few feet thick in the Bighorn Mountain region, but in the Black Hills and some other localities it is 50 feet thick and is known as the Minnekahta limestone. It contains Permian fossils, and as fossils of that age also occur in local limestone beds to within 150 feet of the top of the red beds, these beds are nearly if not all of that age. Possibly the deposition extended far into the Triassic and even into the earlier Jurassic, but there is no definite evidence in regard to this. In most localities there is evidence of uplift and erosion of the Chugwater red beds at an interval prior to the deposition of the marine later Jurassic beds of the Sundance formation.

JURASSIC SEA.

In the Bighorn Mountain region the Jurassic was a period of varying conditions, shallow and deep marine waters alternating. The materials are nearly all fine grained and indicate waters without strong currents. Some of the earliest deposits are fine-grained sandstones or sandy shales, in part ripple-marked, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of subsidence, if not during an arrest of subsidence. An extensive marine fauna and limestone layers in the upper shales of the Sundance formation indicate that deeper water followed, but more sandy sediments appear near the top, indicating the resumption of shallow-water conditions.

CRETACEOUS SEA.

During the Cretaceous period deposits of various kinds, but generally uniform over wide areas, gathered in a great series, beginning with such as are characteristic of shallow seas and estuaries along a coastal plain, passing into sediments from deep marine waters, and changing toward the end to fresh-water sands and clays, with marsh vegetation. The earliest deposits constitute the Morrison formation, a widespread mantle of fine-grained materials, mixtures of clay and fine sand, with thin, irregular bodies of coarser sand deposited by streams or along shores, and with occasional thin beds of limy sediments. Huge saurians were abundant, as is shown by the frequent occurrence of their remains in the deposits, though it is possible that this abundance is due mainly to increased mortality or more favorable conditions of preservation, or both.

Morrison time was succeeded abruptly by a change to conditions under which the coarse-grained, cross-bedded, massive, basal conglomerates and sandstones of the Cloverly formation were deposited. Although the deposits change abruptly and there is occasional local channeling of the surface of the soft Morrison deposits, the erosion appears to be of remarkably small amount, and no more than would be expected to result from the strong currents bearing coarse sand and pebbles. It is believed that there was no great interval of uplift and erosion following Morrison deposition, for if there had been the soft deposits would have been widely removed. It is a significant fact, indicating regular succession, that some of the saurians of Morrison time continued into the next epoch. The coarse deposits of the lower part of the Cloverly were derived from sources not clearly located and spread by strong currents over a wide area. In the earlier stages there were some coaly deposits, but apparently no such coal beds as are found in the Black Hills region. The coarser beds are usually less than 50 feet thick, and give place to massive clays and sandy clays, mostly of purplish color, not unlike the Morrison beds, which usually have a thickness less than 100 feet and are supposed to represent the Fuson formation of the Black Hills. The Dakota sandstone seems often not to be recognizable, but, as there is no unconformity at the top of the Cloverly formation, the sediments of Dakota time are no doubt represented by deposits which are not characteristic. At the beginning of the Benton there was everywhere in the region a rapid change of sediments to dark-colored, fissile shales. These are the products of a later Cretaceous submergence, in which marine conditions prevailed, and it continued until several thousand feet of clays were deposited during the time of the Benton, the Niobrara, and the Pierre. In Benton time there were occasional thin deposits of sand, especially at first and in the middle, when some fine-grained sandy beds were laid down, now known as the Mowry beds. The calcareous sediments of the Greenhorn limestone in the middle of the Benton are not represented in the Bighorn region, and the Niobrara sediments were clays to the north and sandstone to the south, lacking the calcareous, chalky ingredient which characterizes them in other regions to the south. The period of Pierre deposition was long, for over 3,000 feet of dark clays accumulated in most of the region, being deposited slowly under very uniform conditions. The retreat of the sea during later Cretaceous time resulted first in extensive bodies of brackish water, which spread sand over the clay beds, and then in fresh waters, which deposited the sands, clays, and marsh materials of the Laramie and later formations. In this region there was an uplift of moderate prominence in the early part of this time, possibly caused by a fault along a portion of the east slope of the Bighorn Mountains. It was of sufficient magnitude, however, to afford erosion products from beds down to the Cambrian, some of the materials of which appear in a long lens of conglomerate extending from a point southwest of Sheridan for 40 miles southward to Crazy Woman Creek. Deposition of finer grained materials progressed during and following this uplift, and several thousand feet of shales and sands of the De Smet formation accumulated, including scattered beds of carbonaceous materials, which are now lignite coal, in some cases 20 feet or more in thickness. It is believed that this epoch extended into early Eocene time.

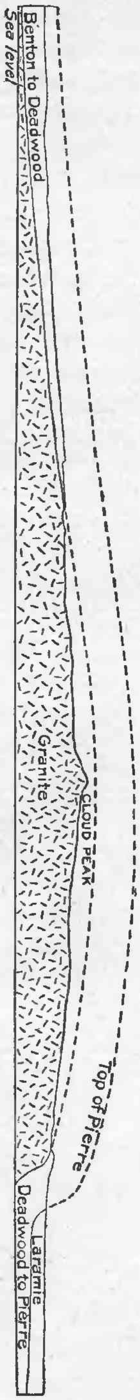


Fig. 13.—Cross section of highest portion of Bighorn uplift, showing probable erosion of strata from Pierre to Deadwood. Vertical and horizontal scales the same. Looking north.

EARLY TERTIARY MOUNTAIN GROWTH.

Extensive uplift took place in the Rocky Mountain province in early Tertiary time. This fact is clearly indicated in most of the mountain regions, where Oligocene deposits lie on an eroded surface having the general outlines of the present configuration, a relation which indicates that the uplifts were truncated and the larger outlines of their topography established in early Eocene time. Where the great mass of eroded material was carried is not known, unless it was to the west and southwest of the Bighorn Mountains, where it constitutes the Bridger and Wasatch beds. Some idea of the extent of erosion in the Bighorn lift is given in fig. 13, which represents the approximate profile of the Pierre and underlying formations continued over the uplift. Probably some of the later deposits also extend over the dome.

LATER TERTIARY FRESH-WATER DEPOSITS.

Oligocene and overlying deposits were laid down by streams and local lakes, and finally covered much of the Northwest to a level now far up the flanks of the various mountain ranges. Erosion has removed them from most of the higher regions where they formerly existed, especially along the steeper slopes. Some deposits of supposed Tertiary age remain in the center of the Bighorn Mountains at altitudes of from 8,000 to 9,000 feet, and occur along the front range at altitudes of from 6,000 to 7,000 feet. They are probably the remnants of much more extensive sheets.

QUATERNARY CONDITIONS.

Several small glaciers remaining in the higher portions of the Bighorn Mountains are diminutive remnants of much more extensive bodies of ice which formerly occupied the principal valleys of the highlands. In this respect the history of the Bighorn Mountains is similar to the history of other high ranges similarly situated in the western part of the United States. The glacial history of those mountains is complex, and the great glaciers, which have left the most distinct records of themselves, were the successors of earlier ones, the marks of which have been partly effaced by weathering and erosion. There is evidence that the Bighorn Mountains were occupied by glaciers during two widely separated glacial epochs, and there is some suggestion that there may have been glaciers at a still earlier time.

ECONOMIC PRODUCTS.

MINERAL RESOURCES.

GENERAL STATEMENT.

Although in the Bighorn uplift there is an extensive area of the old crystalline rocks, they appear to give but little promise of yielding valuable mineral deposits. Much of the area has been prospected, but only a few claims have been worked to any notable extent, and as yet they have not paid expenses. Gold and copper have been found in small amounts, and it is claimed, perhaps erroneously, that platinum was detected. The red beds surrounding the uplift contain large deposits of gypsum. Beds of bentonite and nodules of phosphate of lime occur in the Colorado shales, and inexhaustible supplies of limestone and building stone are obtainable from the mountains. Extensive beds of lignite coal underlie portions of the adjacent plains on both sides of the mountains, and these are mined profitably. Clays for brickmaking and other uses are available at many localities, but are in limited demand. Promising prospects of gold and copper occur in the Bridger uplift.

COAL.

The principal coal mines are near Sheridan and Buffalo, but lignite deposits occur in a wide area of the De Smet formation and could be much more extensively developed than they are at present. The largest mines are at and near Dietz, on Big Goose Creek, 7 miles below Sheridan, where there is a succession of strata, as shown in fig. 1, page 62.

The 7-foot bed of coal has been extensively mined. The overlying layer of hard sandstone thins out about half a mile back in the mines and the two coal beds unite. The coal is of good quality for lignite, but slacks easily on exposure to the air. It is used on one section of the Chicago, Burlington and Quincy Railroad, about 30 locomotives having been specially modified for burning it. Besides supplying the railroad, the coal is shipped to local dealers in both east and west, especially at points in eastern Wyoming and Montana. It supplies some coal to the city of Sheridan, but the greater part of the coal used by the citizens of that place is furnished by other mines along Big Goose and Beaver creeks.

The Dietz tunnel has been worked back into the hills about 1½ miles. It rises with a slight incline for a short distance and then runs nearly on a level only a few feet below the surface of the ground. There are several side entries to the main tunnel, which lead into rooms. The mine is kept well timbered, and as fast as the rooms are worked out the timbers are removed and the walls allowed to cave in. In 1902 a shaft was sunk 150 feet deep, about half a mile northeast of the old tunnel. In this shaft the 7-foot seam mined in the old tunnel was penetrated at a depth of 40 feet, and then a second bed 10 feet thick at a depth of 140 feet. This lower bed contains a harder and, as regarded by the miners, a better coal than that found in the old tunnel. It does not slack easily in the air, and, according to tests made, it is a good quality of steam coal. From the bottom of this shaft there is a main entry 10 feet deep, running over one-fourth of a mile in a northeasterly direction, with side entries in process of construction. This shaft is equipped with a modern derrick, new engines for hoisting, and an elevator for loading coal on the railroad cars. The output of the Dietz Company is said to be 60 cars a day during the busy season, and the coal sells at the rate of $2 a ton.

The coal mines on Owl Creek, 2 miles northeast of Beckton, owned and operated by R. S. Addleman, were opened in 1897. The main tunnel is 800 feet long and runs northeast to southwest, or nearly at right angles to the dip, which is about 4° NE. In 1902 there were 12 rooms 200 feet long, 18 feet wide, and 7 feet high. The coal deposit is 18 feet thick in its thickest portion, and 12 feet of this is good coal, but only 7 feet, near the middle of the bed, is worked. The production is about 4,000 tons a year, which sells at $1 a ton at the mine. Half a mile east, in Big Goose Creek Valley, the same bed is opened at the Big Goose coal mine by H. Timm. Mining was begun in 1890, and in 1902 the main tunnel was 600 feet long with two side entries 240 feet long, and had 6 rooms. The mine is operated only part of the year and has an output of 5 tons a day, valued at $1 a ton at the mine. It is used mainly in Sheridan and is entirely satisfactory for domestic use. Two and a half miles southeast, on the east side of Beaver Creek Valley, is Nelson Brothers' coal mine, which has been in operation since 1899. The bed is the same one as in the other mines, but it is 21 feet thick without a parting. It dips about 4° NE. The company is working only 9 feet of the bottom of the bed. There is a main entry 350 feet long, with numerous rooms 18 feet wide and 9 feet high. The mine is well timbered and has a tramway in the main entry. Eight men are employed in winter and two in summer. The average output is 15 tons a day in winter, which sells at $1.25 a ton at the mine.

In the vicinity of Buffalo the lignite coals are of considerable economic importance, as they are mined extensively for local use. There are four principal beds which outcrop in a zone of moderate width, passing north and south a short distance east of Buffalo. The beds generally vary from 5 to 12 feet in thickness and lie in a series about 200 feet thick, which dips very gently to the northeast. The principal mines are within 3 miles of Buffalo and lie to the east and north. Monkers & Mather's mine is about 1 mile east of the town and is the principal producer. Its annual output averages about 5,000 tons, and the selling price is about $1.50 a ton at the mine. The workings are underground and the section is shown in fig. 14. The lower 7-foot bed is probably the lowest deposit of importance in this region. The upper 7-foot bed of this mine appears to be at the surface at the Bodan mine, a mile north, near the mouth of Rock Creek, where it locally thickens to 12 feet. Here it is mined to a moderate extent in winter. A mile farther east is the abandoned Foot mine, where the coal is 8 feet thick, but the deposit here is on fire. The coal of this bed or an adjoining one shows at intervals northward to the south end of Lake De Smet, where its thickness is about 5 feet and where it was formerly worked.

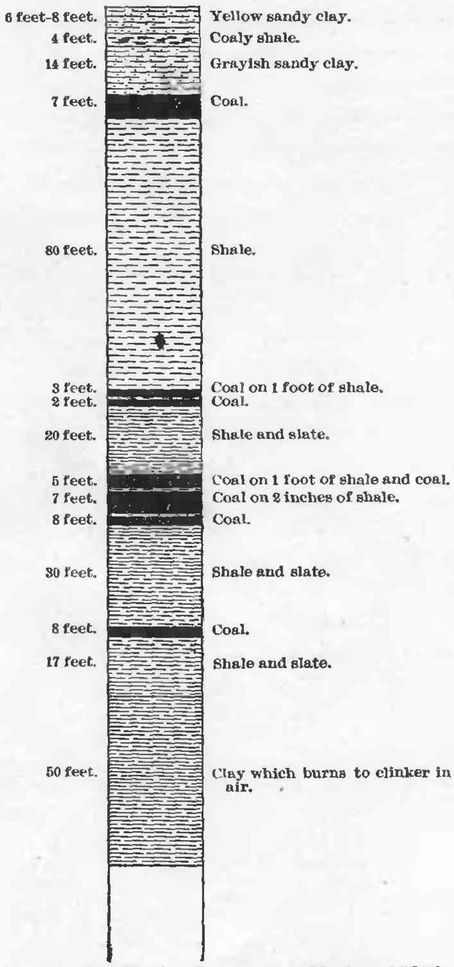


FIG. 14.—Section of coal measures at Monkers & Mather's mine east of Buffalo, Wyo.

At the Mitchell mine, 2½ miles east of Buffalo, a coal bed 6 to 8 feet thick is worked. It lies a short distance below the lower clinker bed. Two miles southwest of Long's ranch a coal bed 6 feet thick is mined to a moderate extent for local use. Its quality is said to be not very good.

GOLD.

At intervals during the past decade attempts have been made to develop gold mines in the vicinity of Bald Mountain, but the results have not been encouraging. The basal gravels of the Deadwood formation, especially where mixed with disintegrated portions of the underlying granite, contain fine-grained free gold, but the values are low and the distribution irregular. The highest assays reported are $2 a ton, but the amount is usually so much less that the workings have not been profitable. At a point about 2 miles west of the abandoned Bald Mountain cabins a mill with jig machine was in operation in 1903, working the disintegrated sandstone and granite at the base of the Deadwood formation, but it is stated that only small portions of the material yielded paying results. Some of the small intrusive dikes, or chimneys, about Fortunatus mill are reported to contain some gold, but the value is low and the extent of mineralization is small.

Another locality at which the basal sandstone of the Deadwood formation has been found to contain gold is at the head of Kelley Creek, southwest of Buffalo. At this place a 3-stamp mill was built several years ago, which obtained a small product, but apparently without sufficient profit to give encouragement to continued operations.

The granite area of the Bighorn uplift has been extensively prospected for metallic minerals, but the results appear to be not encouraging. Small amounts of free gold occur in quartz veins connected with the diabase dikes in the granite, but the values are low. There are several prospects on the headwaters of East Fork of Big Goose Creek. The work was begun in 1898 and, though the results have appeared promising, no ore has been produced. A 350-foot tunnel is projected at one of the mines. The rock is a dark-gray granite containing some pyrite and a trace of copper. Assays of gold showing $4 a ton are reported. In one opening $12 of gold and $7 of silver a ton were found.

Considerable prospecting has been done in two large dikes southeast of Willitt Creek. The minerals are galena and pyrite, occurring in small streaks in quartz along diabase contacts. A few small prospects have been made in a quartz vein about a mile north of Tongue River cabin. A mine on the ridge southwest of the mouth of South Fork of Tongue River, belonging to the Nickel and Copper Refining Company, has been worked at intervals since 1896, but is now abandoned. There is a shaft 180 feet deep, with buildings and extensive machinery. The shaft is sunk along the contact of a large dike of peridotite and a quartz vein, but apparently very little mineral was found. It is stated that platinum was one of the principal objects of the enterprise. Extensive prospecting was done at intervals along the dike, which has a length of about 3 miles. Traces of gold are found in gravels and sands along some of the streams flowing out of the mountains, but they have not been sufficiently promising to lead to any placer mining.

Rich gold prospects have recently been found in the crystalline rock area in the center of the Bridger uplift, 7 miles southwest of Deranch. The metal appears to be free and is partly in quartz veins and partly in association with copper ores. The extent of the deposit has not been ascertaind, but numerous claims have been located and doubtless these will soon be thoroughly explored.

Very little prospecting has been done in the high ridges about Cloud Peak, and possibly some of the great dikes which traverse the granite in that region may carry minerals of value, such as gold or even platinum and the rare earths, some of which now have considerable economic importance. The dike rocks contain magnetite and titanic iron, but they are intimately intermixed with the other constituents and consequently are of no value. Assays of ordinary rock from the two largest dikes showed no traces of valuable metals.

COPPER.

Copper minerals, mainly malachite and red oxide, appear occasionally in the granite, and in the vicinity of Bull Camp and Okie's store considerable prospecting has been done. Small amounts of moderately high-grade ores are obtained, mainly from quartz veins in the vicinity of the diabase dikes. The principal prospects are east and southwest of Bull Camp, one of the most extensive being near Beaver Creek, 3 miles east-southeast of that place. Here a shaft has been sunk 40 feet, but only a small amount of copper ore was obtained. Apparently the mineral is in minute veins, widely scattered through the rock, and no bodies of economic importance appear.

On a branch of South Fork of Wolf Creek, southwest of Walker Prairie, several efforts have been made to develop a copper mine in a 15-foot quartz vein in the granite. A shaft has been sunk 56 feet and crosscuts have been made. The ore is mainly malachite, occurring in irregular veins in the quartz. Some galena also occurs, and part of the vein carries gold amounting to from $3.50 to $4 a ton. The quartz vein at this locality extends about 3 miles southwest and the same distance east of this place, passing under Deadwood sandstones at Walker Prairie. Near its northeastern end, at Walker's mine, where it is about 25 feet wide, it has been prospected to some extent. A small amount of pyrites was obtained, which carried small values of gold.

Copper minerals have been recently discovered in the granite area in the uplift of the Bridger Range, a few miles southwest of Deranch. One vein has been opened, which shows a body of moderate size of high-grade ore, consisting of oxides and sulphides. The openings are not yet sufficiently extensive to exhibit fully the extent and value of the deposit. As stated in the preceding paragraph, considerable gold occurs with the copper minerals of this locality.

GYPSUM.

The gypsum in the Chugwater formation, on both sides of the mountain, is of excellent quality, in every way suited for the production of stucco or plaster of Paris. This product is prepared by calcining and powdering the mineral, which is a combination of sulphate of lime and water. The beds of gypsum occur generally near the base of the formation, and a thickness of 10 to 15 feet is usually presented. Much of the material is of pure white color and is nearly pure. Owing to the lack of a local market and the fact that the value of plaster of Paris is too low to cover freight charges for long shipments, this resource has no promise of development at present.

BENTONITE.

Bentonite has not been observed in the immediate vicinity of the Bighorn Mountains, but, as it occurs in adjoining areas and appears generally to be present in the

Colorado shale, probably it will eventually be found. It occurs at two horizons, one below and the other above the hard shale or Mowry member. The mineral is a pale greenish-buff clay of compact texture and of such porous structure that it will absorb several times its bulk of water. On account of this absorbent quality it has a moderate market value for several uses.

LIMESTONE.

The limestones of the mountain slopes are in the main sufficiently pure for lime burning or for smelting flux, but there is very little demand for these products in the region. No analyses have been made to ascertain the chemical character of the rocks.

BUILDING STONES.

Many of the rocks in the mountain portion of the area are more or less well suited for building stone. Some of the granites are massive, have a fine appearance when polished, are relatively free from minerals which cause stains on weathering, and may at some time be valuable for shipment for building. Some of the limestones in the Madison formation are of very satisfactory texture and appearance, and possibly portions of them could be worked for marble, especially the upper member. The Tensleep sandstone is usually massive, even textured, and of white or light-buff color, so that, if nearer to markets, it might be advantageously worked as a freestone. The red sandstones of the Chugwater formation are of very pleasing color, but they are mostly too soft to be of value for building. Large supplies of rough stones for foundations and similar uses are obtainable from the De Smet, Piney, Parkman, and Cloverly sandstones and the hard ledges in the Sundance formation.

PHOSPHATE.

The spherical concretions occurring in the lower portion of the Colorado formation consist mainly of phosphate of lime, and, as they could be obtained in large numbers by means of suitable excavating machinery, they may at some time be utilized as a source of phosphate.

PETROLEUM.

At various localities along the sides of the Bighorn and associated uplifts some of the sandstones and sandy shales contain petroleum. This material usually appears in springs or seeps in small valleys, and so far has been found only in limited amounts. The principal occurrences are on the sides of the uplift which rises east of the South Fork of Powder River, in T. 38, R. 82 and T. 40, R. 79, the latter being in the valley of Salt Creek. Details regarding these occurrences are given in bulletins by the late Prof. W. C. Knight.[a] Nine wells have been sunk on Salt Creek to depths of from 800 to 1,200 feet, some of which yield oil. The output of this field in 1905 averaged 35 barrels a day. This is hauled 50 miles to Casper, at a cost of $2.80 a barrel, where it sells at an average rate of $7 a barrel. The horizon appears to be the sandstone at the base of the Pierre, or possibly the next sandstone stratum below in the upper part of the Colorado.

[a] University of Wyoming bulletins, Petroleum series, Nos. 1 and 4.

Oil springs of small volume occur in the vicinity of Bonanza, but a number of wells sunk in that field have failed to obtain a supply. The oil in the springs is from a horizon in the lower portion of the Colorado.

ASPHALTUM.

A deposit of asphalt occurs in the Tensleep sandstone, on the west slope of the Bighorn Mountains, in sections 28, 29, 32 and 33, T. 52, R. 89. The thickness is stated to be 6 feet, but the area has not been ascertained. The material consists largely of asphalt intimately mixed with coarse sand.

WATER SUPPLY.

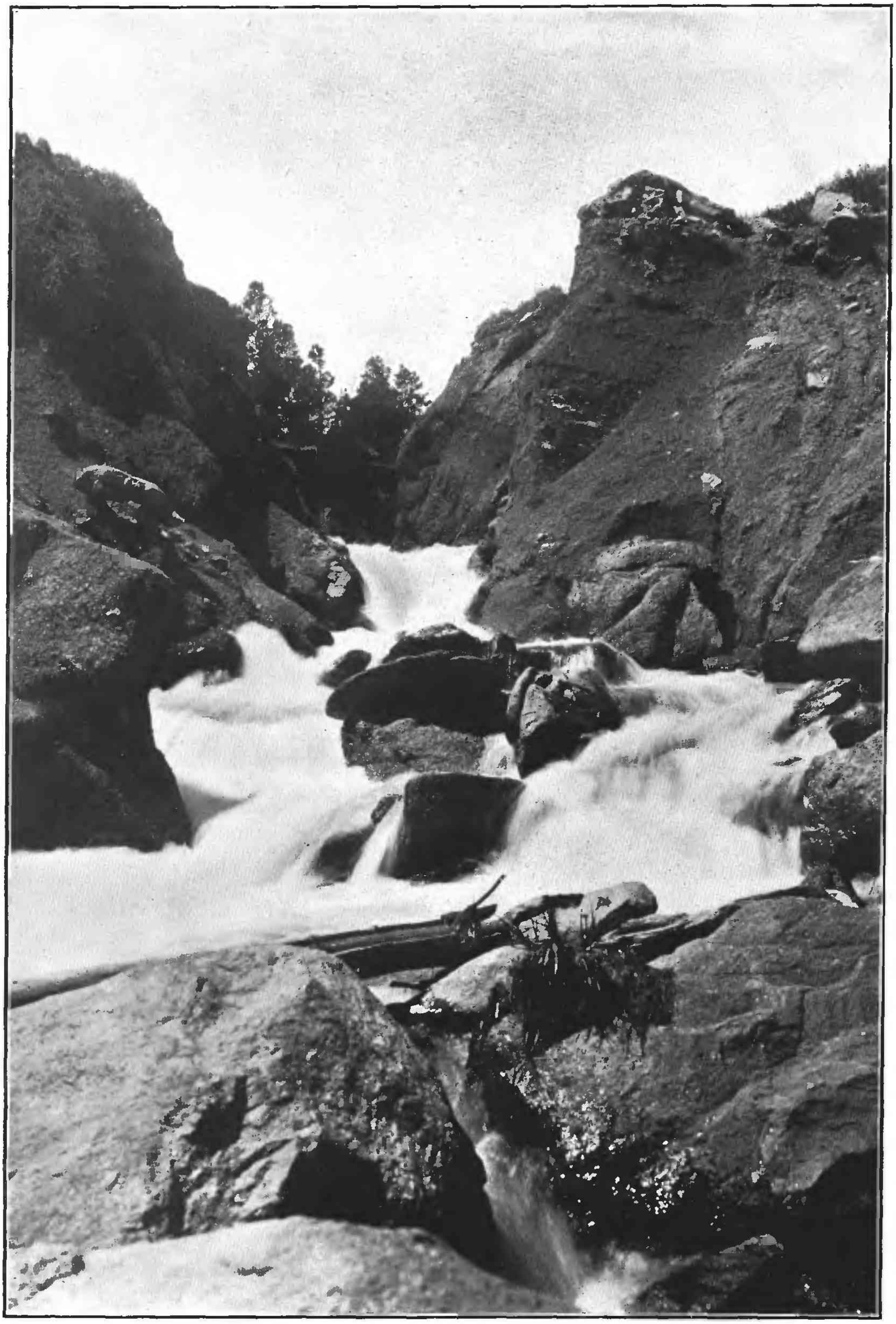
SURFACE WATERS.

Owing to the relatively large precipitation and especially to the heavy snowfall on the Bighorn Mountains, the numerous streams which head in the higher slopes gather a large flow, most of which is carried out of the mountains and across the plains on either side. Although the volume is greatest during the early summer, when the snows begin to melt rapidly on the mountains, the flow of the larger streams continues throughout the summer and autumn, in most cases in fairly good volume. In the higher portions of the mountains a large amount of snow remains all summer, melting gradually and thus sustaining a constant flow in innumerable small rivulets heading in the snow banks. The glaciers also, about Cloud Peak, yield a constant flow throughout the melting season. Portions of the mountains are forested and this, together with the large amount of grass and other plants, conserves much of the summer rainfall, so that it flows out of the highlands gradually. Extensive forest fires have so denuded many areas that only bare rocks or hard soil remain and from such areas the run-off is rapid. With increased growth of forests by protection against fires, the amount of available water from the mountain area could be materially increased. The greater part of the water which runs out of the mountains is utilized by irrigating ditches in the adjoining plains, where the extent of practicable irrigation is limited by the amount of water available. With an increased volume of water an increased acreage of the arid lands of the adjoining plains could be reclaimed and made serviceable. The flood waters of most of the streams go to waste, for but little provision has been made to hold them. It is probable that eventually all these waters can be stored and applied to irrigation. In storing waters in the plains area, the large amount of evaporation, about 6 feet per year, has to be provided for. This loss is very much less in the mountains, where the air is more humid and much of the evaporation is compensated for by increased rainfall. Many of the lakes in the central area can be utilized for storage reservoirs, by dams of moderate height. Provision for this has already been made by a dam at Cloud Peak Lake, and plans have been developed for damming some of the other lakes.

The principal streams of the Bighorn Mountains are Bighorn, Little Bighorn, Powder, and Tongue rivers, and Shell, Big Goose, Little Goose, Paintrock, Tensleep, Piney, Clear, Crazy Woman, Badwater, No Wood, and Buffalo creeks.

BIGHORN RIVER CROSSING PLAINS JUST AFTER LEAVING CANYON.

Wide alluvial flat in soft strata. Looking northeast. Photograph by J. Stimson.



FALLS ON DIVERSION DITCH FROM BIG GOOSE CREEK.

High in east slope of Bighorn Mountains. The water is carried across a low divide and then plunges down slope into head of creek, making the cut shown above. Photograph by J. Stimson.

Bighorn River traverses the Bighorn Basin from south to north and flows across the north end of the Bighorn uplift in a deep canyon. It is a large stream, usually averaging about 200 feet wide and 3 feet deep. Its volume at the mouth of the canyon is reported to average 3,200 second-feet. The result of a measurement made near its mouth in August, 1879, showed a discharge of 5,865 second-feet.

Little Bighorn River rises in the slopes east and north of Bald Mountain and, rapidly gaining in volume by the contributions from many side branches, flows northeastward through a deep canyon, which ends near the Montana-Wyoming line. No records are available as to the amount of water, but the average summer flow appears to be not less than 100 second-feet.

Tongue River rises in the northern portion of the main granite area and throughout the summer it is fed extensively by melting snow banks. It flows eastward through a deep gorge in the limestone front range and receives a small additional volume of water from Little Tongue River. From gagings of the combined flow, made at Dayton in 1903, the volume was found to vary from 109 to 845 second-feet, the latter amount in the early floods of June. Later in the summer the average flow was from 109 to 125 second-feet.

Big Goose Creek is the principal affluent of Tongue River and carries a large body of water in the early summer (400 to 600 second-feet), but diminishes greatly in volume as the season advances. In 1898 the maximum discharge of this stream was 595 second-feet, and the minimum 17 second-feet, but as these gagings were made below all the important diversion ditches the records give no information of the volume of water which the stream contains, but only that which runs to waste. Little Goose Creek has a flow about two-thirds as large as that of Big Goose Creek.

Piney Creek drains the northeastern slopes of Cloud Peak and adjoining ridges. There are three principal branches, all of which unite a short distance east of the limestone front range, through which they pass in canyons. The main creek at Kearney, Wyo., showed a maximum volume of 818 second-feet in June, 1903, with gradual diminution to 329 second-feet after the floods had subsided, and decreasing to less than 40 second-feet during midsummer. The average for July of that year was 152 second-feet; August, 66 second-feet; September, 46 second-feet; and October, 76 second-feet. On September 6 of the previous year the discharge was only 21 second-feet.

Clear Creek drains the eastern side of the high mountain ranges south of Cloud Peak. There are three branches, which unite at the limestone front range. It derives much of its flow from the large bodies of snow and ice which continue to melt during all the summer. The average monthly discharge of the creek at Buffalo is about 100 second-feet, but in autumn it usually diminishes to about half this amount, while in June it often rises to from 250 to 350 second-feet. This creek, with its tributaries, irrigates more land than any other stream rising in the Bighorn Mountains. The volume of its water supply, therefore, is a matter of considerable importance. Measurements of its flow at Buffalo were begun in 1889 and continued to 1900, when it was decided that the records would no longer be of value on account of the large amount of water diverted from the creek for irrigation purposes above the gaging station. The maximum discharge recorded was 853 second-feet, in June,

1898. From the north it receives a number of branches, which rise in the mountains. The first of these is French Creek, which is normally a stream of very small flow, but its supply has been greatly increased by a diversion ditch from North Fork of Clear Creek. Rock Creek is the principal affluent of Clear Creek from the north. It rises on the lower slopes of the granite area and receives water from two main forks and Sayles and Johnson creeks. The total average flow is estimated to be about 25 second-feet. The various forks of Crazy Woman Creek lie on the lower granite slopes and carry a moderate volume of water, which is so extensively diverted for irrigation on the plains that the volume of water in the main stream eastward is very small, and in dry weather the flow ceases entirely. The various streams which rise on the lower slopes of the limestone front range and among the ridges in the plains eastward run only during rainy weather, when for a short period they carry a large run-off, which soon subsides.

Tensleep Creek drains the southwestern slopes of the high central granite range. It flows southward through large deposits of glacial drift and finally through a deep canyon, which ends at the red valley on the east side of Bighorn Basin. It empties into No Wood Creek at Tensleep. No gagings of its flow are on record, but it appears to have about the same volume as Clear Creek.

Paintrock Creek drains a large watershed on the west side of the Cloud Peak area and receives water from numerous large branches, the most important of which is Medicinelodge Creek. This stream and the main Paintrock flow out of canyons into the red valley east of Hyattville. No records of gagings are available, but the combined flow of Paintrock and Medicinelodge, near Hyattville, probably averages nearly 75 second-feet during the summer season. Much of the water is diverted for irrigation.

Shell Creek drains the northern portion of the high granite area and flows across the Bighorn Basin to Bighorn River. In character and volume it is a stream very similar to Big Goose Creek, on the opposite side of the mountain. A measurement of this stream, July 3, 1901, 6 miles above Shell, Wyo., showed a discharge of 451 second-feet, but a measurement made 1 mile above this point, July 21, showed a discharge of only 76 second-feet. Shell Creek receives from the north numerous small branches, the largest of which are Granite, Cedar, Horse, and Beaver creeks, but they are streams of very small volume.

The southeastern slopes of the Bighorn Mountains are drained by several branches of Powder River—North, Middle, and Red Forks, and Buffalo and Beartrap creeks. These streams rise in the high slopes mainly from 7,000 to 8,500 feet above sea level, where there is much snow and a moderately high rainfall. In consequence they carry a good volume of water, especially North Fork, which rises on the south slopes of the high granite ranges in the higher portion of the uplift. Its flow is estimated to be about 25 second-feet in midsummer. Middle and Red forks are streams of about equal size, having about 20 second-feet of flow and joining in township 42. Beartrap Creek, the principal affluent of Red Fork, is a small running stream. Buffalo Creek is a small but important branch of Middle Fork, which runs throughout the year.

No Wood Creek flows along the base of the southwestern side of the Bighorn Mountains and receives numerous small running streams, most of which rise in

A. CLOUD PEAK LAKE ON SOUTH FORK OF SOUTH PINEY CREEK; ALTITUDE, 9,732 FEET.

Lies in glaciated rock basin; now dammed to serve as a storage reservoir. Looking northeast. Photograph by J. Stimson.

B. KEARNEY LAKES ON NORTH FORK OF SOUTH PINEY CREEK; ALTITUDE, 9,156 FEET.

Valley in granite, dammed by moraine. Looking northeast. Photograph by J. Stimson.

springs in the higher slopes. The principal affluent is Tensleep Creek, above which are Spring, Otter, Little Canyon, Lost, Deep, Trout, and Lonetree creeks, all of which are small flowing streams and each of which adds from 3 to 10 second-feet to No Wood Creek, part of which is utilized for irrigation.

In the southwestern end of the Bighorn Mountains rise the headwaters of Badwater Creek and its branches, Clear, Sioux, and Bridger creeks, which gather considerable water from springs on the higher slopes. Much of the flow in Badwater Creek is utilized for irrigation, but ordinarily it flows through to Bighorn River in moderate volume.

The Bridger Range contains no large streams, except the Bighorn River at its western end. A few creeks on the north slope carry a small volume of water to Buffalo Creek, but the few streams on the south and east sides have insufficient volume to flow more than a short distance.

UNDERGROUND WATERS.

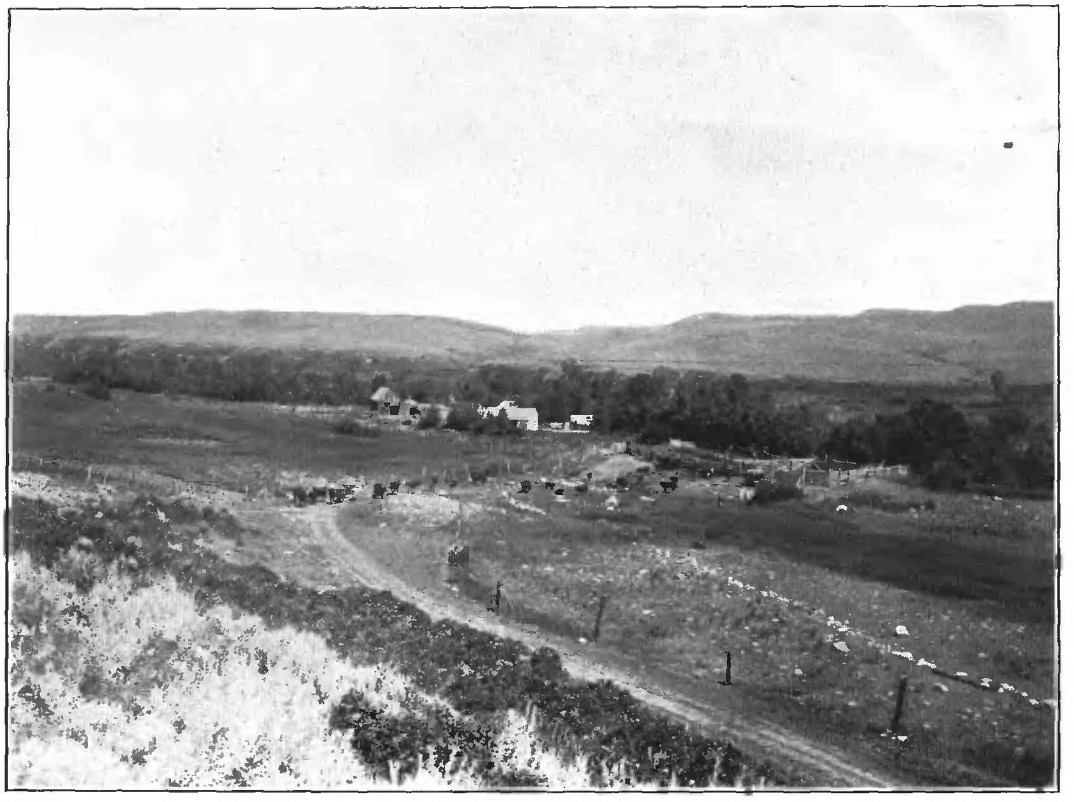
Several of the formations exhibited in the Bighorn uplift consist of porous sandstones, which undoubtedly contain water in their underground extension. Their outcrop zones are on the mountain slopes, where water is imbibed, and their dip carries them underneath the adjacent plains, where most of them are covered by shales and other rocks of an impervious nature. To this extent the conditions for underground waters are favorable, but in portions of the region, owing to the general prevalence of steep dips, all of the water-bearing beds in the older formations pass rapidly to such a great depth in their extension under the plains that they could not be reached by ordinary well boring. The principal underground conditions are shown in the cross sections on Pl. XXXVIII.

The Cloverly sandstone, which represents the principal water-bearing horizon under the central Great Plains, lies at a depth of several thousand feet throughout the region adjoining the Bighorn Mountains on the northeast, so that it can not be reached practicably by wells. The sandstones of the Deadwood and Tensleep formations lie still deeper. On the western and southeastern slopes of the mountains the dips are usually much less and it will be possible to reach some of the water-bearing formations by deep wells. The sandstone of the Cloverly formation would probably afford artesian flows at moderate depths along Shell Creek; below the mouth of Beaver Creek; along Bighorn River from Basin to the canyon in Sheep Mountain, and in the shale area above and below Kane; in the lower lands about Hyattville and west to Bonanza; along the valley of No Wood Creek in the Colorado shale area in townships 45 and 46, and in Kirby Creek Valley. It is only in the valleys, however, that flows could be obtained, and as most of these are traversed by running streams of fine water, wells are not much needed. The Tensleep sandstone lies about 1,300 feet below the base of the Cloverly on the western side of the Bighorn Mountains, and it would be practicable to reach this formation at many points in the areas of Chugwater red beds from Shell to Tensleep, in the vicinity of Crystal, south from Rome nearly to the head of No Wood, and along Buffalo Creek on the southeast side of the mountains. Probably this Tensleep sandstone contains water which would afford flows at many places. In Montana the sandstones of the Cloverly formation could be reached by wells of moderate depth in the Colorado area in the vicinity of Bighorn and Little Bighorn rivers, and probably it would yield flowing water in the lower portions of these valleys. In the plains at the southern end of the Bighorn Basin, north of the southwest end of the Bighorn Mountains and northeast of the Bridger Range, the Cloverly sandstone lies at depths varying from 500 to 2,500 feet, the latter amount at the Parkman-Pierre contact. Sandstones in the upper portion of the Colorado and at the base of the Pierre probably also contain water, and these are about 1,000 feet nearer the surface. Flowing water is to be expected in all the lower lands along Kirby, No Water, and Buffalo creeks. It is probable that flows could be obtained in Warm Spring Valley southeast of Thermopolis at depths of from 300 to 600 feet. The Tensleep sandstone should yield a flow in Buffalo Creek Valley southeast of Thermopolis at depths from 100 to 300 feet.

In the Powder River basin east of the southern portion of the Bighorn Mountains the dips are low and water-bearing sandstones lie at no great depth. Along the Pierre-Colorado contact wells from 1,100 to 1,300 feet deep would reach the basal Cloverly sandstone, and in most of the lower lands a flow should be expected from this source. The two sandstones in the upper Colorado and at the base of the Pierre undoubtedly contain water in all the region south of the North Fork of Powder River. They lie at moderate depths in range 82, the amount gradually increasing to about 1,500 feet at the Pierre-Parkman contact. The Tensleep sandstone contains much water in the area drained by the forks of Powder River, and in the Chugwater area it lies at moderate depths. Along Buffalo Creek its depth is often only 200 to 300 feet, and probably a flow would be found in the vicinity of the creek. Farther east the depth gradually increases, as shown in section 10, Pl. XXXVIII, to 2,600 feet along the Colorado-Pierre contact.

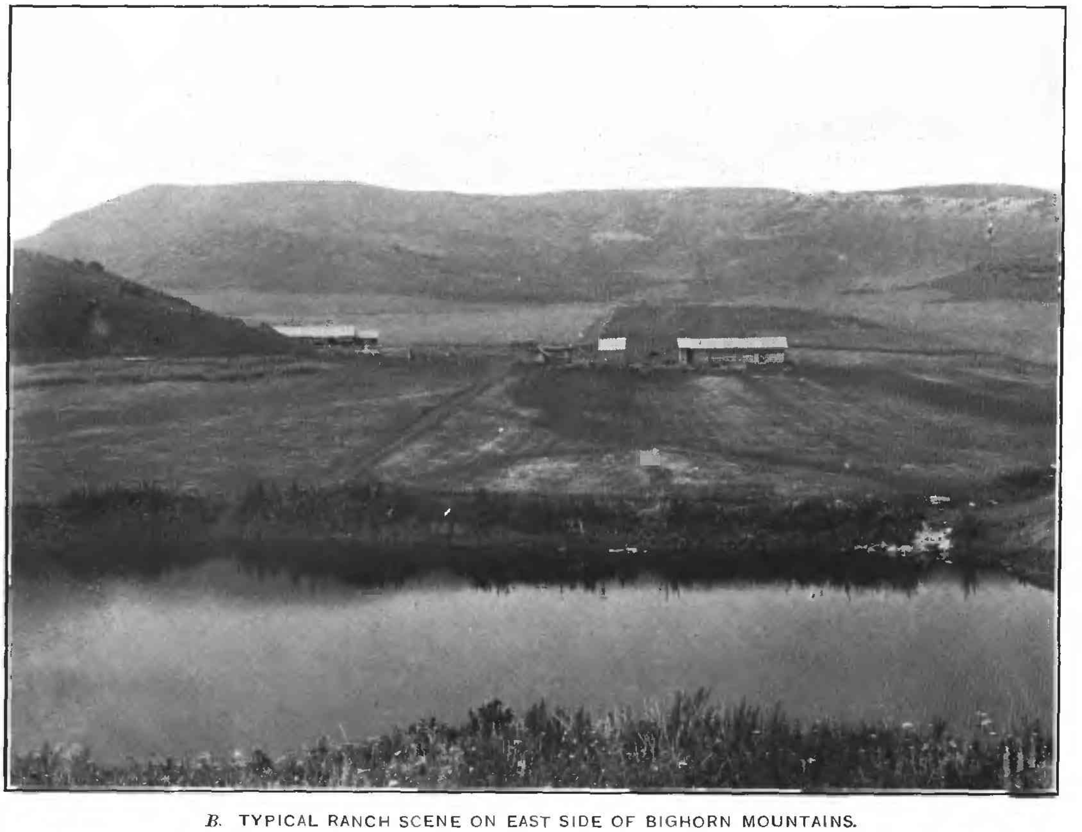
It is difficult to give information as to the underground water conditions in the plains south of the Bridger Range and in the southern end of the Bighorn Mountains because the Bridger formation overlaps most of the sedimentary formations so that their distribution can not be ascertained. Much of the land is sufficiently low for flows, and wells of sufficient depth would penetrate the water-bearing beds which undoubtedly extend along the south side of the uplifts. In T. 39 W., R. 88, wells in the valleys, from 500 to 1,000 feet deep, would have an excellent prospect of obtaining flowing water.

The Parkman sandstone is finer grained and probably contains water, but east of its outcrop zone on the eastern side of the mountain it descends so rapidly that it soon is beyond reach. The sandstones of the Piney and De Smet formations contain a large amount of water, and doubtless in some of the lower valleys of the region artesian flows may be obtained from them. A well several hundred feet deep at Sheridan obtained water in one of the sandstone beds, but it did not have sufficient head to rise to the surface. Numerous shallow wells have been sunk, which nearly always find abundant water in Piney or De Smet sandstone. The alluvial deposits of the valleys all contain water, but, owing to the seepage in the various shale formations, the waters contain considerable alkali at many points, except in the immediate vicinity of the steep mountain slopes.



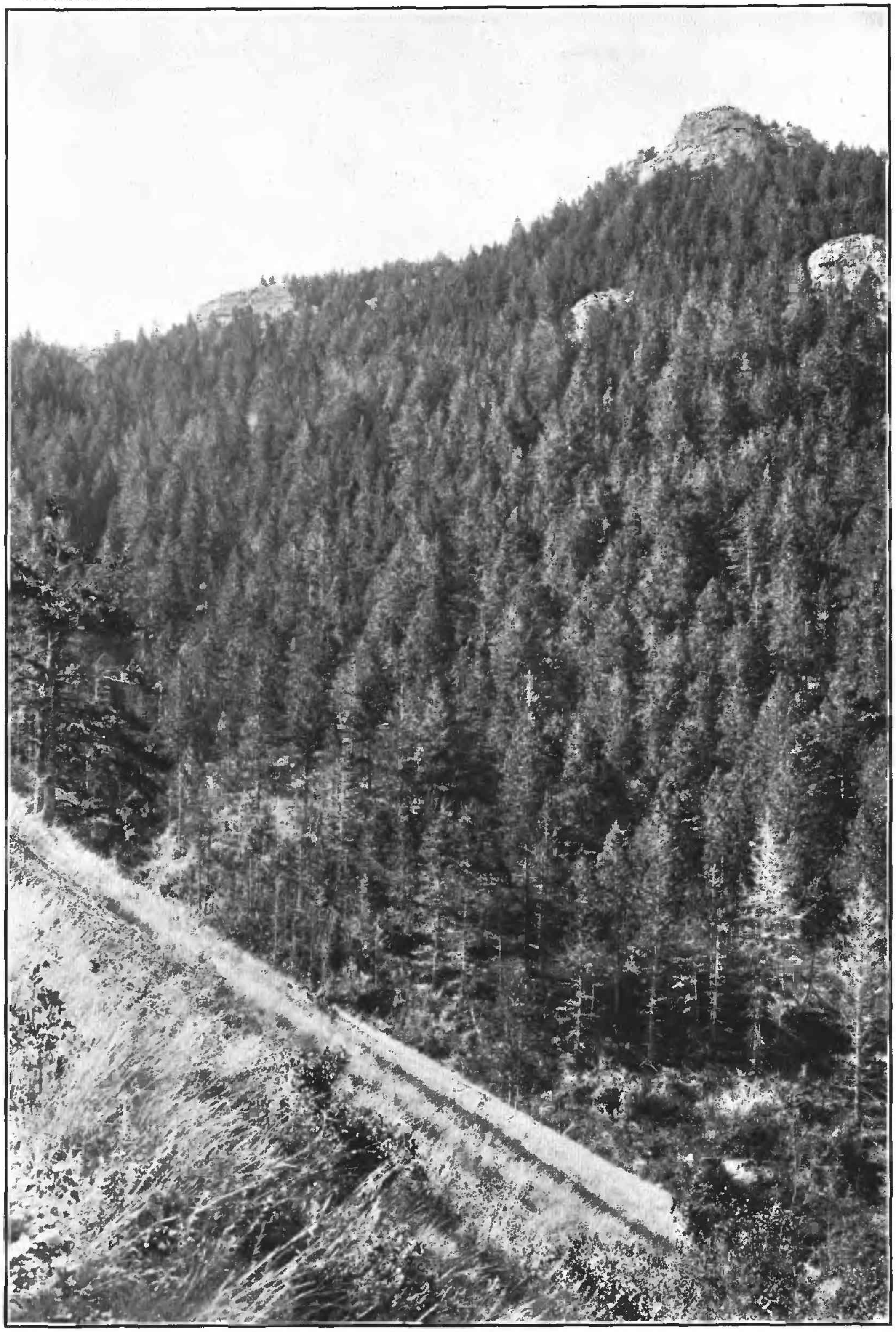
A. TYPICAL RANCH AT FOOT OF BIGHORN MOUNTAINS.

Near Massacre Hill south of Kearney, Wyo. Ridge of De Smet formation in distance. Photograph by J. Stimson.



B. TYPICAL RANCH SCENE ON EAST SIDE OF BIGHORN MOUNTAINS.

Shows reservoir. Photograph by J. Stimson.



TYPICAL FOREST VIEW ON LIMESTONE SLOPES OF CANYON OF BIGHORN RIVER.

Photograph by J. Stimson.

TIMBER.

The mountainous area in the Bald Mountain quadrangle is irregularly forested and though there have been numerous fires much good timber remains. The greater part of the wooded area is included in the Bighorn Forest Reserve, the limits of which are shown on the maps in this report. Nearly all the trees on the reserve are pine, mainly of one species, *Pinus murrayana*, but it is called white pine, yellow pine, jack pine, and lodgepole pine, the different names being applied partly on account of differences in development. The wood is coarse grained and knotty and few of the trees produce large logs, and, as the lumber warps and cracks considerably, it is not regarded as valuable. Another species of pine, *Pinus flexilis*, occurs scattered among the former. The Engelmann spruce occurs in some moist areas along the mountain slopes and the higher portions of some of the canyons. The pine forests occur at altitudes ranging from 6,000 to nearly 10,000 feet. A description of some features of the Bighorn Forest Reserve, with maps showing the distribution of the timber, is published in Part V of the Nineteenth Annual Report of the United States Geological Survey, to which the reader is referred. A typical forest view is given in Pl. XLVI.

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U.

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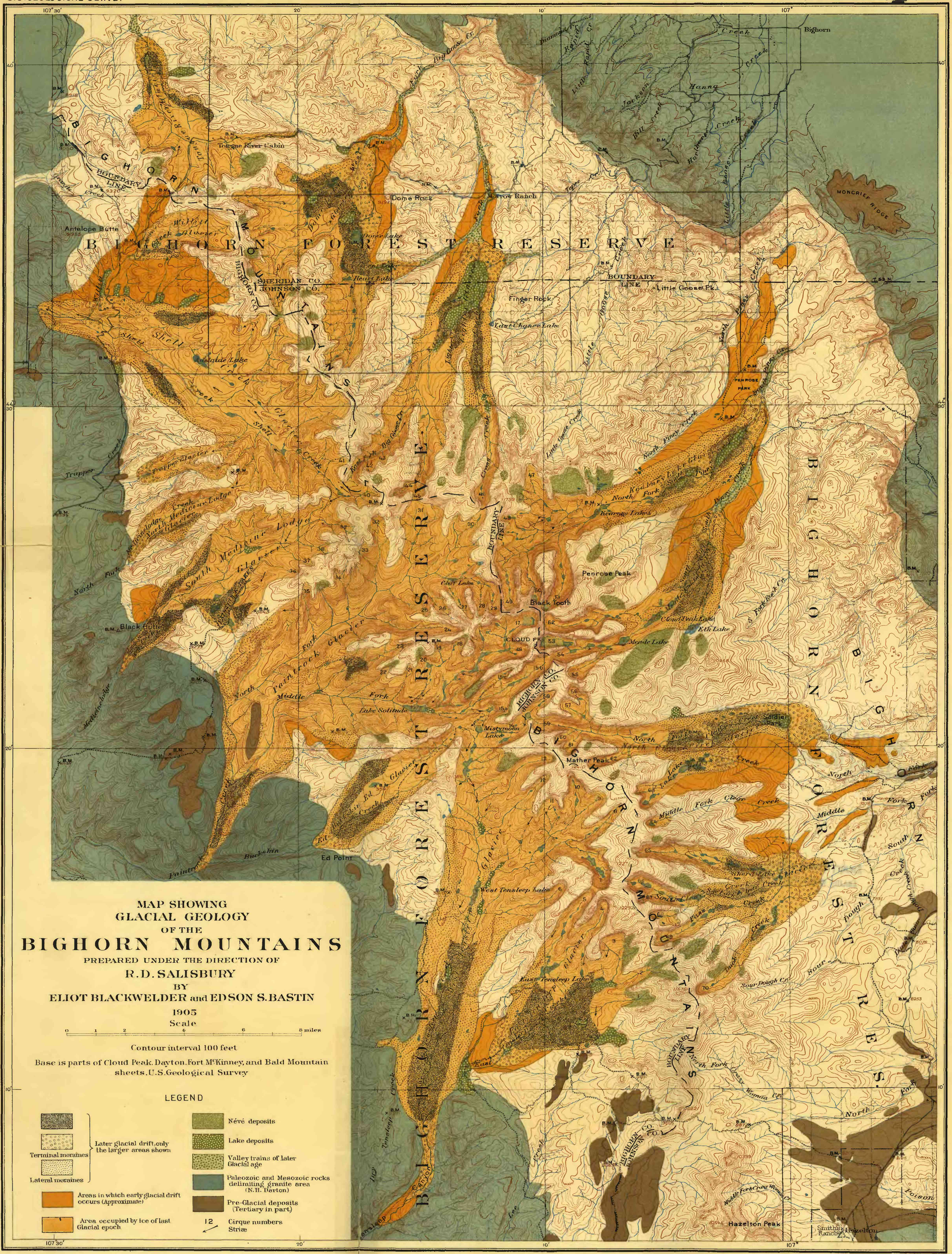
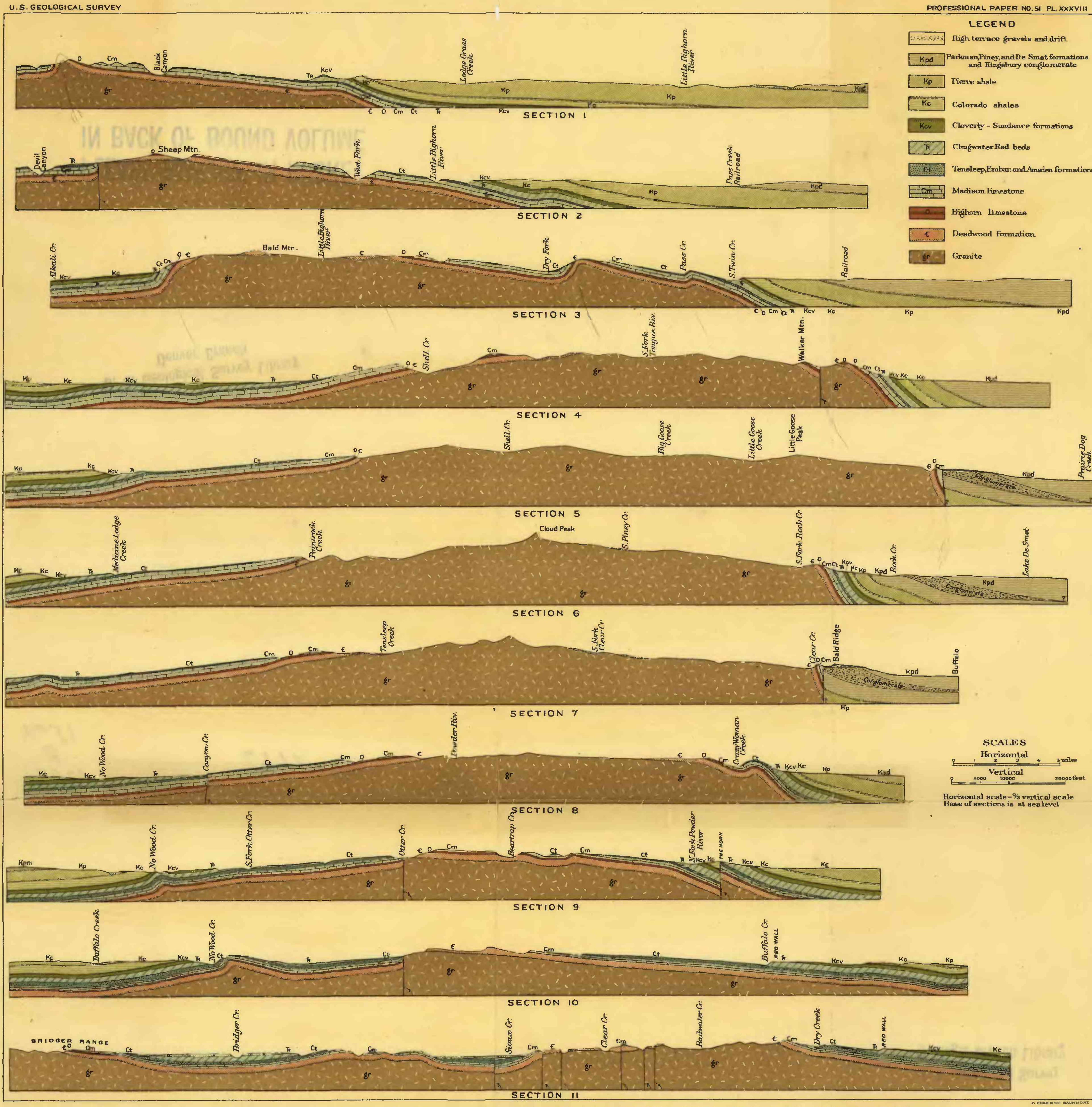
W.

1872—No. 51—06——9


GEOLOGIC MAP
OF THE
BIGHORN MOUNTAINS
WYOMING
BY
N.H.DARTON
1905
Scale
Contour interval 250 feet.
Datum is mean sea level
Topography north of latitude 44° mainly from maps by U.S.Geological Survey
Principal roads
LEGEND
QUATERNARY
Glacial drift
TERTIARY
Sands, sandstones, clays, gravels, and bowlders
De Smet and Piney formations and Kingsbury conglomerate
Parkman sandstone
Pierre shale
CRETACEOUS
Colorado formation
Cloverly formation
Morrison formation
JURASSIC
Sundance formation
TRIASSIC? and Permian
Chugwater formation
CARBONIFEROUS (Pennsylvanian)
Tensleep, Embar, and Amsden formations
CARBONIFEROUS (Mississippian)
Madison limestone
ORDOVICIAN
Bighorn limestone
CAMBRIAN
Deadwood formation
PRE-CAMBRIAN
Granite
Dikes, mostly diabase
MONTANA
WYOMING
BOUNDARY LINE
SHERIDAN
JOHNSON
BIGHORN
WASHAKIE
NATRONA
SHOSHONE INDIAN RESERVATION
SECTION 2
SECTION 5
SECTION 6
SECTION 7
SECTION 8
SECTION 9
SECTION 10
BIGHORN RIVER
Point Lookout
Medicine Mt.
Cloud Peak
Black Mt.
Sheridan
Buffalo
Dayton
Ranchester
Parkman
Big Horn
Banner
Kaycee
Basin
Copper Mtn
Lost Cabin
Tensleep
Bighorn

(200) B 6777


MAP SHOWING
GLACIAL GEOLOGY
OF THE
BIGHORN MOUNTAINS
PREPARED UNDER THE DIRECTION OF
R. D. SALISBURY
BY
ELIOT BLACKWELDER and EDSON S. BASTIN
1905
Scale
0 1 2 4 6 8 miles
Contour interval 100 feet
Base is parts of Cloud Peak, Dayton, Fort McKinney, and Bald Mountain sheets, U.S. Geological Survey
LEGEND
Terminal moraines
Lateral moraines
Later glacial drift, only the larger areas shown
Areas in which early glacial drift occurs (Approximate)
Area occupied by ice of last Glacial epoch
Névé deposits
Lake deposits
Valley trains of later Glacial age
Paleozoic and Mesozoic rocks delimiting granite area (N. H. Darton)
Pre-Glacial deposits (Tertiary in part)
Cirque numbers
Striæ
BIGHORN FOREST RESERVE
BIGHORN MOUNTAINS
Cloud Pk.
Black Tooth
Penrose Peak
Mather Peak
Hazelton Peak
Moncrief Ridge
Bighorn
Dome Rock
Finger Rock
Little Goose Pk.
Antelope Butte
Black Butte
Ed Point
Lake Solitude
West Tensleep Lake
East Tensleep Lake
SHERIDAN CO.
JOHNSON CO.
BIGHORN CO.
Tongue River Cabin
Penrose Park



CROSS SECTIONS OF THE BIGHORN MOUNTAINS, BY N. H. DARTON