DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 364

GEOLOGY AND MINERAL RESOURCES

OF THE

LARAMIE BASIN, WYOMING

A PRELIMINARY REPORT

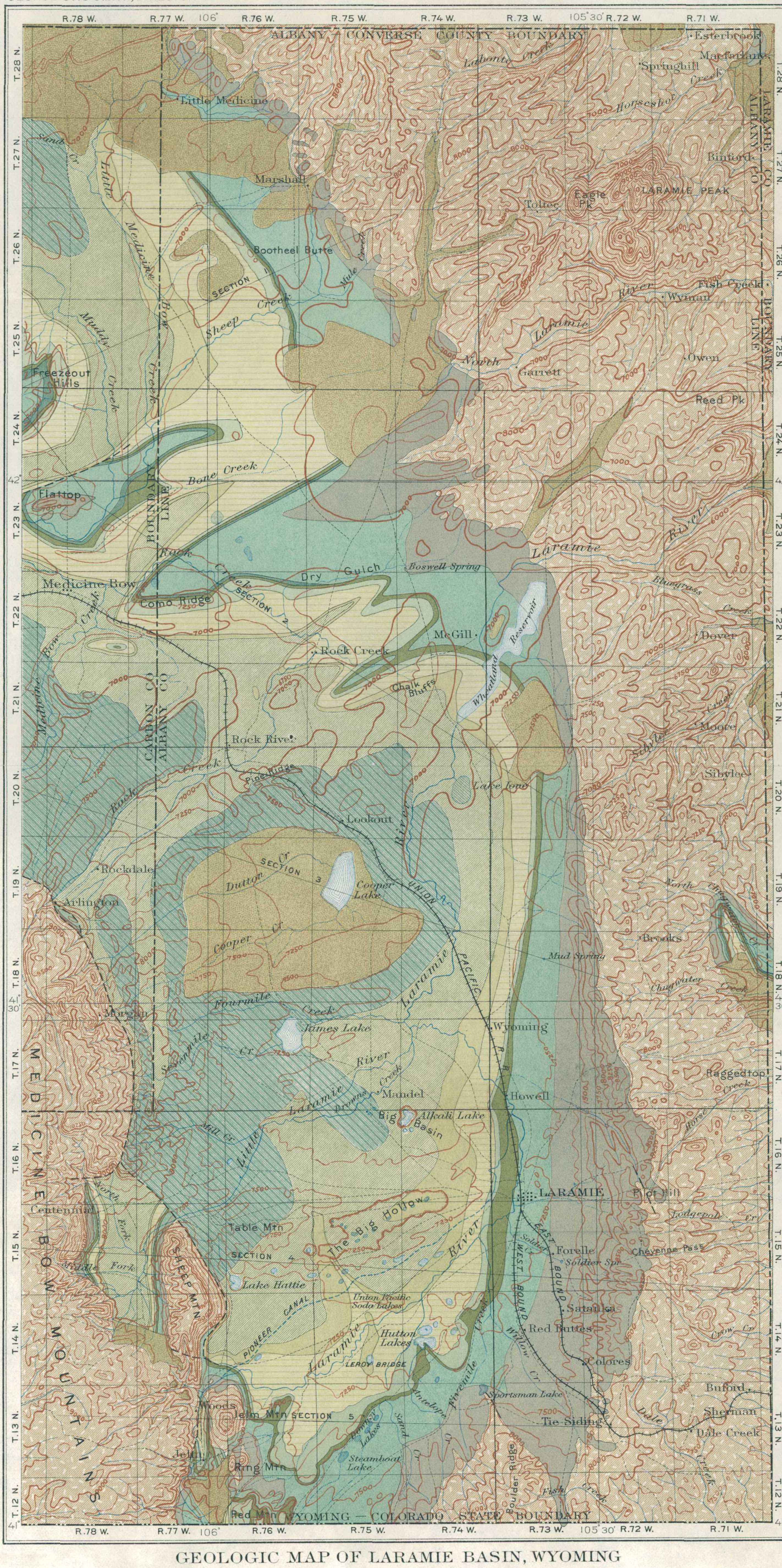
BY

N. H. DARTON AND C. E. SIEBENTHAL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1909

CONTENTS.

ILLUSTRATIONS.



GEOLOGIC MAP OF LARAMIE BASIN, WYOMING

BY N. H. DARTON AND C. E. SIEBENTHAL

5 0 5 10 miles

Contour interval 250 feet.

LEGEND

TERTIARY	CRETACEOUS					CRETACEOUS?	JURASSIC	TRIASSIC? PERMIAN	PENNSYLVANIAN MISSISSIPPIAN	PRE-CAMBRIAN
Gravels, sands, and clay, of several formations	Montana group (upper part)	Montana group (lower part)	Niobrara formation	Benton formation	Cloverly formation	Morrison formation	Sundance formation	Chugwater formation	Casper formation Satanka and forelle included	Granite, gneiss, etc.

-------- Main road — — — Fault

1908

GEOLOGY AND MINERAL RESOURCES OF LARAMIE BASIN, WYOMING: A PRELIMINARY REPORT.

By N. H. Darton and C. E. Siebenthal.

INTRODUCTION.

The region to which this report relates (see fig. 1) includes all of the area usually designated the Laramie Plains and Laramie Basin, or all of Albany County except that part which lies high on the

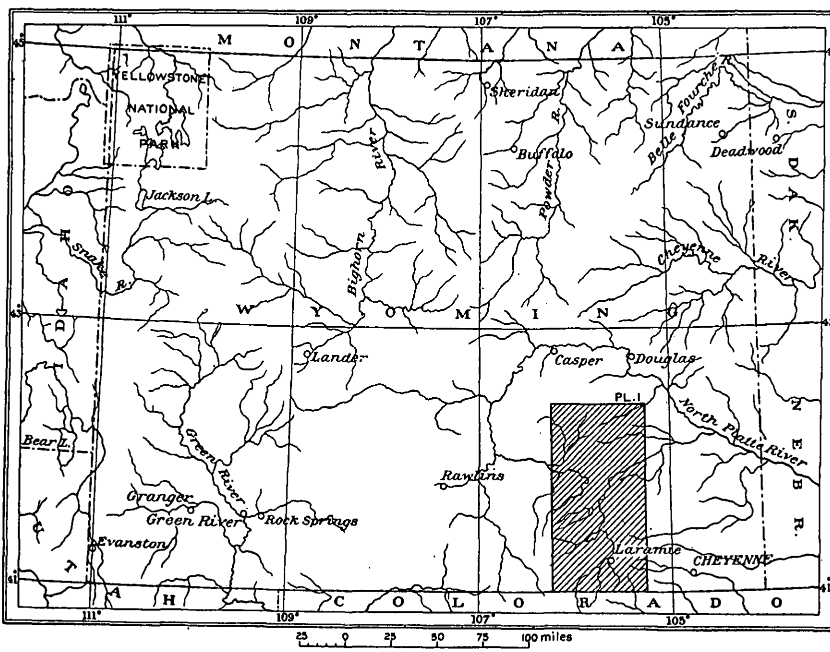


Fig. 1.—Map of Wyoming, showing area treated in this report.

slopes of the Medicine Bow Range. It also includes a small portion of the eastern border of Carbon County.

The investigation, which was made during portions of 1905 and 1906, was undertaken largely for the purpose of determining the conditions under which underground waters might be expected; this involved a study of the geologic succession and structure. The greater part of the area is thinly settled, but as the population increases there will be great need for additional water supply. The surface waters at many points are not satisfactory for domestic use, so that underground waters from artesian wells may prove important.

The geology of the southern half of the area had been set forth in a general way in the report of the Fortieth Parallel Survey, but it was necessary to make a more detailed classification of the formations, to measure their thickness, and to adjust the boundaries and structure to a more accurate base map, in order to obtain a reliable basis on which to make predictions in regard to the underground waters. Incidentally, attention was given to various mineral resources which have been developed in the region, although these have been treated to some extent in bulletins of the State university. The base of the map (Pl. I) which accompanies this report is the result of reconnaissance surveys, except for the portion south of latitude 41° 30′, which is condensed from the maps of the Laramie, Medicine Bow,[a] and Sherman quadrangles of the United States Geological Survey.

GEOGRAPHY.

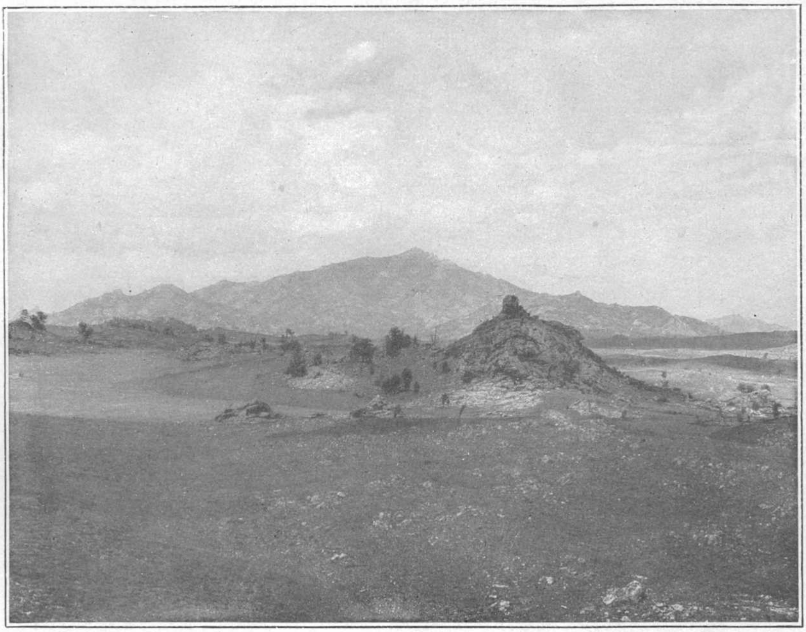
CONFIGURATION.

The Laramie Basin is a wide rolling plain lying between the Laramie Range on the east and the Medicine Bow Mountains on the southwest. To the northwest lie the Freezeout Hills and various high ridges and the valley of Medicine Bow River. The Laramie Mountains are the northern continuation of the Front Range of the Rocky Mountains; they range in altitude from 8,000 feet in some of the lower passes to about 10,000 feet in Laramie Peak. The Medicine Bow Mountains are an extension of one of the inner ranges of the Rocky Mountains, which, in a portion called the "Snowy Range," rises to an altitude of 12,000 feet. The altitude of the Laramie Basin varies from about 7,000 feet in its northern and central portions to 7,500 feet near the Colorado line. The length of the basin is 90 miles, and the width of its wider portion is about 30 miles. The Laramie Mountains on the east rise in a long zone of moderate slopes; the Medicine Bow Mountains on the west are precipitous and have their continuity interrupted by some high outlying masses, of which Jelm and Sheep mountains are especially steep and conspicuous. The Laramie Mountains are crossed by the deep canyons of Laramie and North Laramie rivers, north of which they rise into the prominent range culminating in Laramie Peak. (See Pl. II, *A*.) The range is also crossed by the valley of Sybille Creek and by several wind gaps.

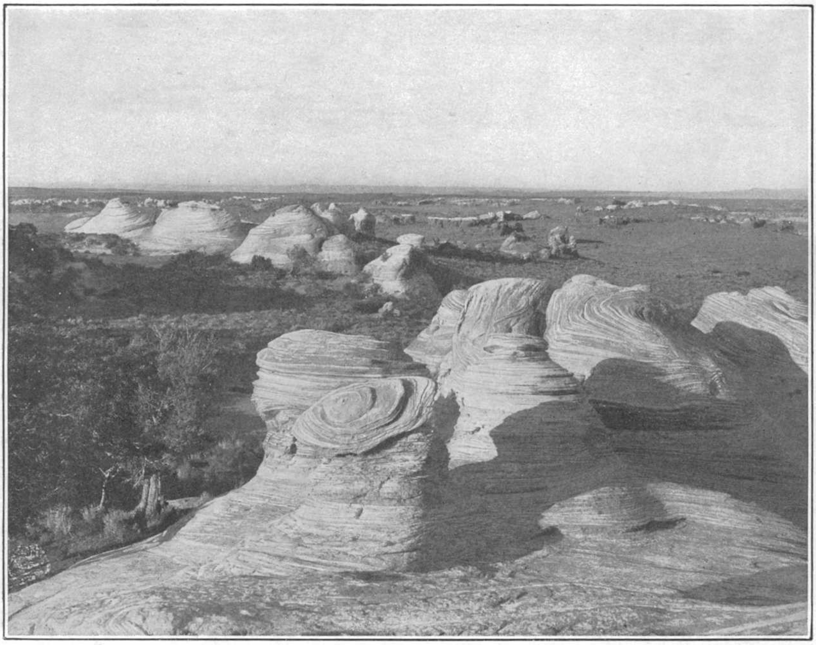
Although the Laramie Basin presents considerable variety of configuration, it consists mostly of broad, shallow, terraced valleys sepa-

---

[a] In preparation.



A. LARAMIE PEAK FROM THE SOUTH.



B. CROSS-BEDDED SANDSTONE OF CASPER FORMATION ON SAND CREEK, WYOMING.

rated by low, flat-topped ridges which are remnants of an earlier terrace system. The valleys of Little Laramie and Laramie rivers are especially wide and flat bottomed. A characteristic view of the Little Laramie Valley is shown in Plate III. The divide between these two valleys west of Laramie is a ridge 300 feet or more in height, containing a depression 200 feet deep, known as "The Big Hollow," which is 9 miles in length and 3 miles in width, with its longer axis trending west-southwest and east-northeast. Big Basin, northwest of Laramie, is similar to The Big Hollow, but is of less extent and lies at a slightly lower altitude. Other notable basins are occupied by Cooper and James lakes.

DRAINAGE.

The greater part of the Laramie Basin is traversed by Laramie River, which finally crosses the Laramie Mountains in a deep canyon and flows out across the Great Plains to join North Platte River. It rises in the Medicine Bow Mountains and other ranges in northern Colorado and receives various branches from the south and west. Little Laramie River is the principal branch, and Sand, Willow, and Fivemile creeks carry a moderate volume of water. Dutton and Cooper creeks are two small streams which head in the east slope of the Medicine Bow Mountains and empty into Cooper Lake. Probably the water of this lake finally finds its way underground into Laramie River. The Laramie receives but few branches from the east; of these, Willow, Soldier, and Spring creeks and a stream northeast of Wyoming station carry a small volume of water. The northwestern portion of the region is drained by Medicine Bow River and its two large branches, Rock and Little Medicine Bow creeks. Medicine Bow River and Rock Creek (see Pl. IV) head in the north end of the Medicine Bow Mountains. Little Medicine Bow Creek and its branches, Sheep and Muddy creeks, head in the plains and mountain slopes to the north and northeast.

A notable feature in the Laramie Mountains is the general eastward drainage, down the wide eastern slope of the range. Sybille Creek and North Laramie River drain small portions of the eastern side of the Laramie Basin and flow across the mountains in canyons.

CLIMATE.

Temperature.—The climate of the Laramie Basin presents the usual features of the northern Rocky Mountains and the higher Great Plains. It is dry and cool, is relatively uniform from year to year, and has a large percentage of sunshine. Meteorological records have been kept at the State university at Laramie since 1891, and their results, summarized on page 10, indicate the principal features.

Monthly means of temperature (°F.) at Laramie, Wyo., 1891–1905.

January	21.6	June	56.6	November	31.1
February	20.3	July	62.3	December	21.8
March	28.4	August	61.9	Mean	40.3
April	37.3	September	51.8		
May	47.4	October	42.1		

Extremes of temperatures and variation of mean annual temperatures at Laramie, Wyo., 1891–1905.

Year.	Highest.		Lowest.		Mean for year.
	°F.	Date.	°F.	Date.	
1891	83	Aug. 13	−13	Dec. 7	40.9
1892	85	July 19	−29	Jan. 11	40.5
1893	87	July 21	− 9	Feb. 27	40.6
1894	88	July 11	−27	Dec. 28	39.9
1895	84	July 27	−30	Feb. 12	38.5
1896	84	June 19, Aug. 14	−27	Mar. 3	41.4
1897	85	July 29	−30	Jan. 27	39.6
1898	88	June 30, July 26	−23	Jan. 26	38.9
1899	87	June 29, July 25	−40	Feb. 12	38.8
1900	91	June 29	−27	Dec. 31	42.6
1901	92	July 20	−23	Dec. 14	40.2
1902	91	Aug. 1	−18	Jan. 26	40.9
1903	84	June 2, July 25, Aug. 3	− 8	Mar. 30	40.1
1904	84	Aug. 22	−16	Jan. 28	41.8
1905	91	July 13	−42	Feb. 12	40.3

It will be seen from this table that the maximum rarely reaches 90°. The higher temperatures are of short duration, and all the nights are cool, the temperature falling rapidly after sunset. Owing to the great dryness of the air the heat is not oppressive. The lower winter temperatures do not continue long but recur in irregular spells, often separated by long intervals of moderate temperature. Strong winds are rare and occur mostly as part of a cold wave or accompanying a thunderstorm in summer.

Precipitation.—The average yearly precipitation at Laramie is 9.9 inches. The monthly averages for fifteen years are as follows:

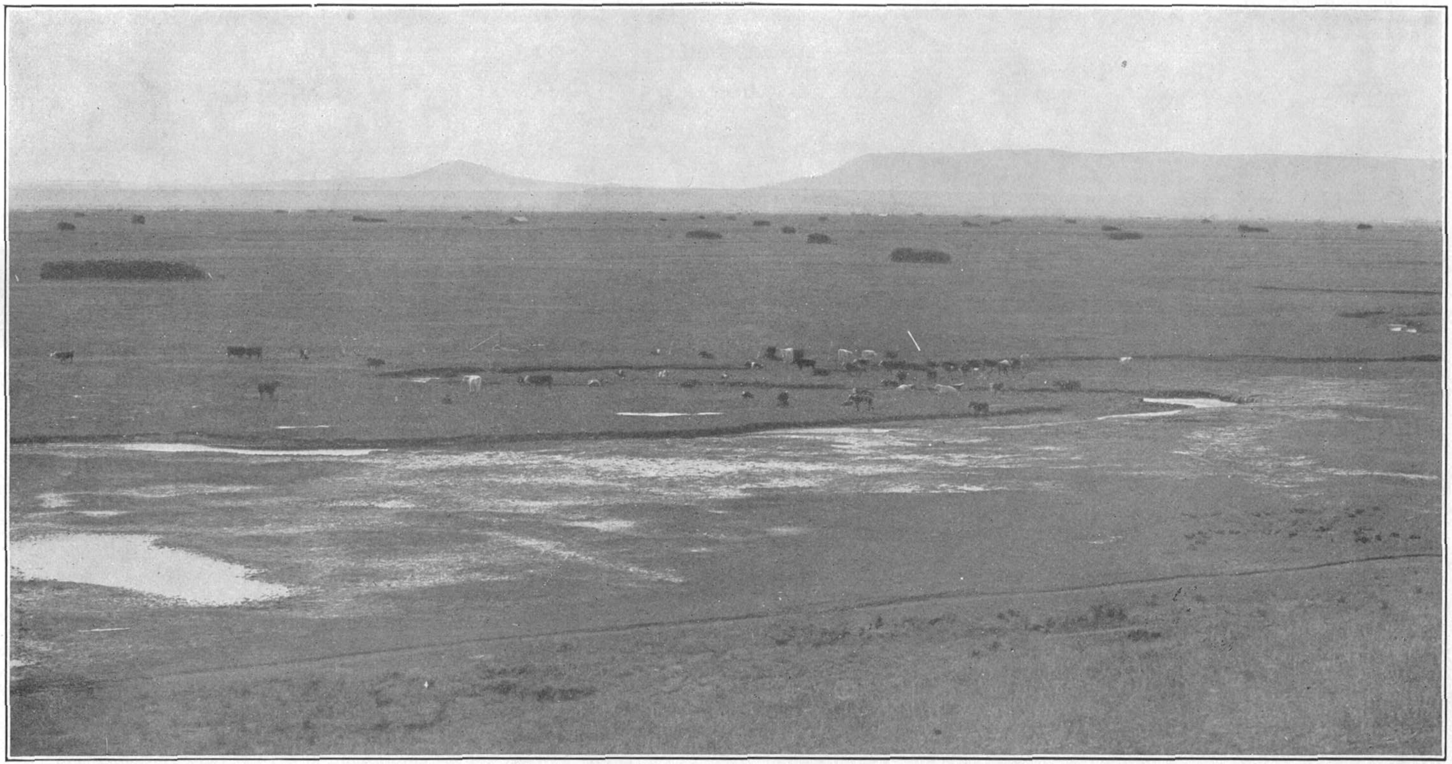
Monthly means of precipitation (inches) at Laramie, Wyo., 1891–1905.

January	0.23	May	1.47	September	0.92
February	.34	June	1.24	October	.79
March	.83	July	1.40	November	.22
April	1.14	August	.99	December	.33

The annual precipitation for the same period is as follows:

Annual precipitation (inches) at Laramie, Wyo., 1891–1905.

1891	13.92	1896	12.80	1901	8.52
1892	12.73	1897	12.48	1902	7.73
1893	3.84	1898	7.63	1903	10.37
1894	7.63	1899	11.84	1904	9.58
1895	11.15	1900	8.53	1905	9.76



VIEW ACROSS LARAMIE PLAINS, LOOKING SOUTHWEST; LITTLE LARAMIE RIVER IN FOREGROUND.

A portion of the precipitation is snow, which falls in varying amounts but seldom lies long on the ground except on the higher mountain slopes. Hail falls occasionally and every few years does more or less damage to crops.

GEOLOGY.

STRATIGRAPHY.

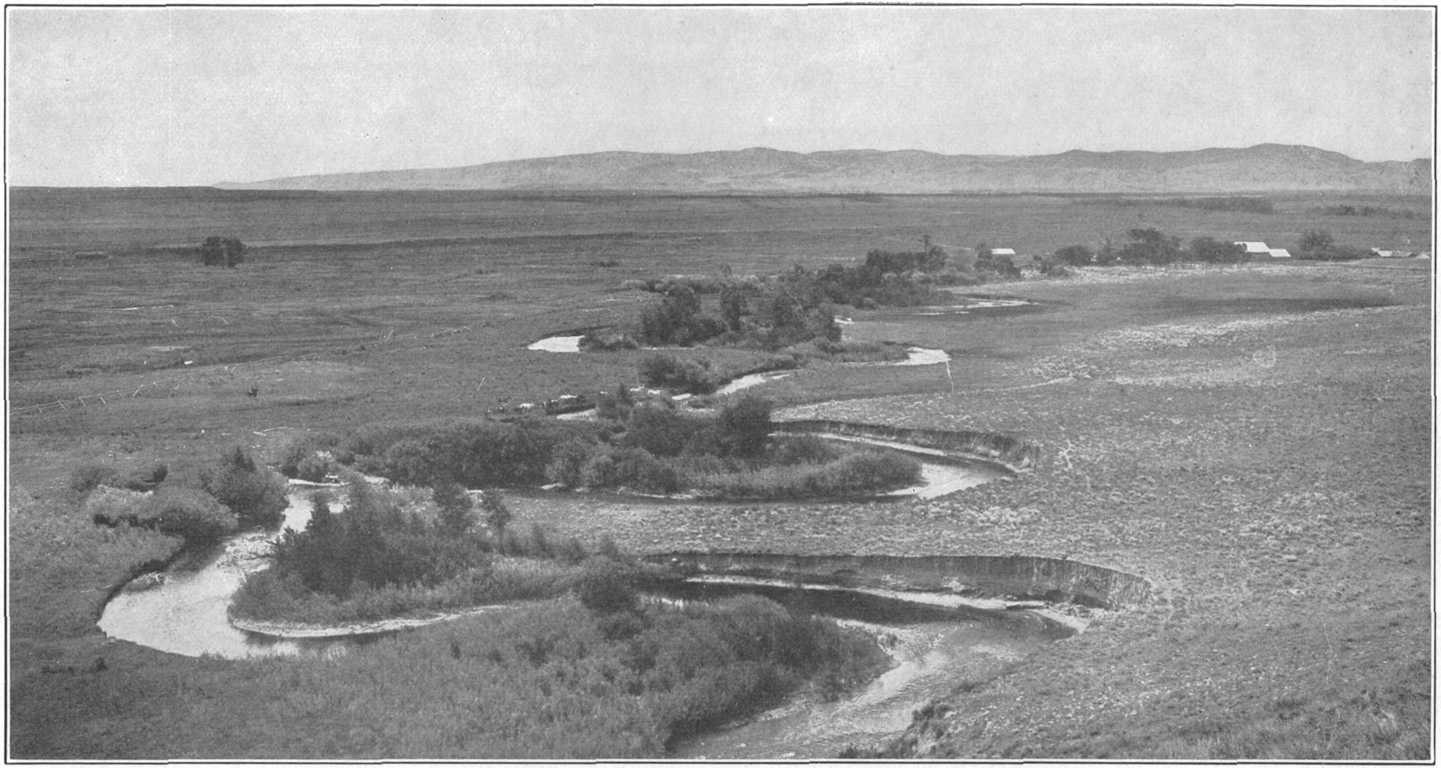
GENERAL RELATIONS.

The Laramie Basin is a syncline lying between the uplifts of the Laramie Mountains on the east and the Medicine Bow Mountains and minor ranges on the west. Its depth is such that it contains about 7,000 feet of Paleozoic and Mesozoic sedimentary rocks, from Carboniferous to late Cretaceous in age, as well as extensive Tertiary and Quaternary deposits. In Plate VIII are given cross sections showing the general structural relations of the rocks. It will be seen that the sedimentary formations consist mainly of a series of thick sheets of sandstone, limestone, and shale, all essentially conformable in attitude, though lacking some systems of the geologic succession. At the base are pre-Cambrian granites, schists, and other rocks. The stratigraphy presents much similarity to the general succession in the Rocky Mountains of Colorado and Wyoming, but it has numerous distinctive local features. The following is a list of the Mesozoic and older formations exhibited in the basin, with a general statement as to thickness, characteristics, and age:

Generalized section of Mesozoic and older rocks in Laramie Basin, Wyoming.

Formation.	Character.	Average thickness.	Age.
		Feet.	
Montana	Upper part: Sandstones and carbonaceous shales with local coal deposits.	1,280+	Upper Cretaceous.
	Lower part: Dark shales representing the greater portion of the Pierre shale.	3,000	Do.
Niobrara	Impure chalk rock and calcareous shale weathering to light-buff color.	180	Do.
Benton	Gray shales, with hard shales and fine sandstone (Mowry shale) near middle and buff sandstone near top.	550-1,300	Do.
Cloverly	Coarse, massive, buff sandstones separated by gray to purple shales.	150	Upper(?) and Lower Cretaceous.
Morrison	Massive shales, greenish gray, buff, and maroon, with thin limestone layers.	115-200	Lower Cretaceous (?).
Sundance	Soft sandstones overlain by greenish-gray shales.	0-120	Late Jurassic.
Chugwater	Red shales and soft sandstone, with gypsum deposits at and near base.	1,200	Triassic (?) and Carboniferous (Permian).
Forelle	Gray limestone	1-20	Carboniferous (Pennsylvanian).
Satanka	Red shale, with local gypsum	0-240	Do.
Casper	White to purple limestones and dolomites and gray and white sandstones, which to the south and west give place mostly to red and white, coarse sandstones.	500-1,007½	Carboniferous (Pennsylvanian-Mississippian).
Granite, schists, etc.	Crystalline rocks of various kinds penetrated by diabase and other dikes.	....	Archean or Algonkian or both.

The granites and other crystalline rocks present considerable variety, which it is not the purpose of this report to map or describe. They constitute a floor upon which lie sediments of Carboniferous age, but in their extension to other regions they are overlain by Cambrian rocks, so that they are known to belong to the Algonkian or Archean. No Cambrian, Ordovician, Silurian, or Devonian sediments appear in the Laramie Basin and apparently the Mississippian series of the Carboniferous is absent also, except in small amount to the north. The upper Carboniferous is extensively represented by a formation consisting mostly of limestones to the north, and of coarse red beds to the southwest. This formation is overlain by finer grained red beds which, in part at least, may include a representative of the Triassic. The marine Jurassic, which follows, is similar to that of the Black Hills and of central and western Wyoming, but it thins out and disappears near Rock Creek. The next formation is the Morrison shale, about 200 feet thick, which presents its characteristic features. Representatives of the Cloverly formation appear throughout the basin; the hard, coarse sandstone at its base (supposed to represent the Lakota sandstone of the Black Hills region) is its most conspicuous feature. The great series of Upper Cretaceous shales has a thickness of 5,000 feet or more and constitutes the principal material at the surface or under the Quaternary in the Laramie Basin. At the base is the Benton formation, in which, however, the middle limestone member (Greenhorn) appears not to be present. The Mowry shale member and upper sandstone (upper Carlile) are prominent features in the group. The Niobrara formation, with its calcareous sediments, is conspicuous throughout the area. The Montana group occupies a broad basin west and north of Laramie and a smaller area in the basin of Little Medicine Bow Creek. Its lower part comprises a thick succession of gray shales such as are characteristic of the Pierre, and its upper part consists largely of sandstones, possibly overlain by Laramie. The Tertiary deposits occur in irregular areas and probably include several formations, but the only one that can be correlated is in the Little Medicine Bow basin and consists of White River deposits of early Oligocene age (Chadron formation). The Quaternary comprises numerous terrace deposits of wide extent, the lowest of which are the broad alluvial flats along the rivers.



ROCK CREEK VALLEY, NEAR ROCK RIVER STATION.

CARBONIFEROUS SYSTEM.

CASPER FORMATION.

General character.—The name Casper is here proposed for the rocks of Carboniferous age (chiefly Pennsylvanian) capping Casper Mountain and extending along both sides of the Laramie Range. For the greater part of its course the formation consists of light-colored limestones and dolomites merging downward into gray and brown sandstones which lie upon the pre-Cambrian crystalline rocks. In their southern extension, as shown by Knight,[a] these sediments gradually change into "Red Beds," which consist largely of coarse red sandstones south and southwest of Laramie. At the top, in the vicinity of Laramie and for some distance north and south, there is a conspicuous and persistent bed of limestone which is quarried for lime.

The Casper formation occupies the western slope of the Laramie Mountains, a prominent range which from Sybille Creek southward has an average height of 1,000 feet above the Laramie Plains and constitutes the main divide. The south end of the area occupied by this formation extends about half a mile south of the Colorado line in the narrow syncline between Boulder Ridge and the Laramie Mountains. The syncline between Boulder Ridge and the Medicine Bow Mountains also is occupied by the Casper formation, the outcrop of which is mostly in Colorado. Irregular outcrops occur around the base of Jelm, Ring, and Sheep mountains and the formation appears along the foot of the mountain slopes on both sides of the Centennial Valley. Along the fault at the foot of the Medicine Bow Mountains, north of the Centennial Valley, the formation lies at great depth below the surface. The upper sandstone appears in an outcrop several miles long in the center of the anticline north of Medicine Bow, in the ridge known as Flattop.

Thickness.—The thickness of the Casper formation varies considerably. The maximum observed was in Gilmore Canyon southeast of Laramie, where 1,007½ feet were measured. At the head of Sybille Creek and north of Laramie River the amount is considerably less than this, being apparently not more than 500 feet. On Sand Creek, near Pulpit Rock, the thickness is 500 feet, and it is about 600 feet in a section measured on the northwestern slope of Red Mountain. An approximate measurement a mile west of Boswell's ranch on Laramie River, at the Colorado state line, gave 1,000 feet and another in the Centennial Valley about 850 feet.

---

[a] Knight, W. C., The Laramie Plains Red Beds and their age: Jour. Geology, vol. 10, 1902, pp. 413-422.

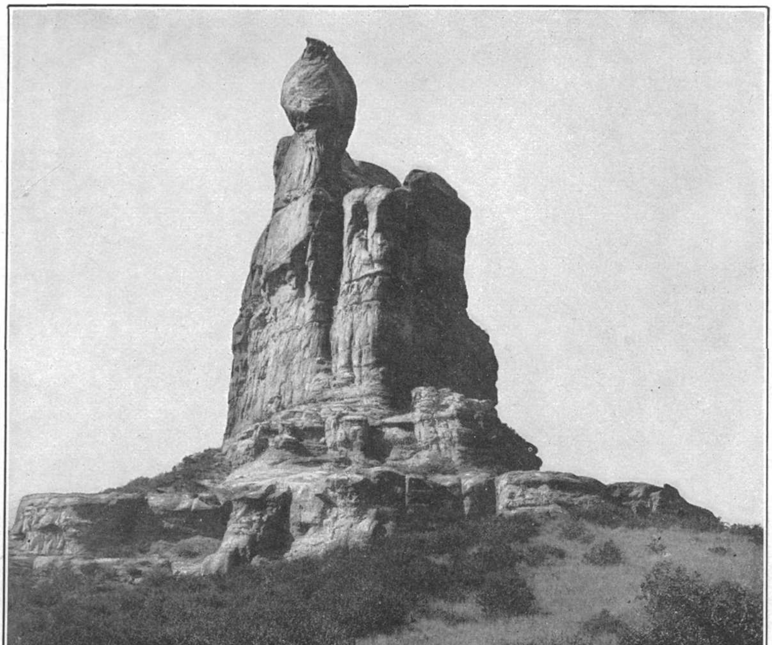
Local features.—The principal features of the Casper and associated formations in the vicinity of Laramie are illustrated in the following well-exposed section in Gilmore Canyon:

Section of Carboniferous formations in Gilmore Canyon, Wyoming.

		Feet.
1.	Forelle limestone	20
2.	Satanka red shale; some red sandstone	232
3.	Sandstone (top of Casper formation)	2
4.	Red shale with a few thin beds of white and red sandstone	120
5.	Red to buff sandstone	65
6.	Limestone, fossiliferous	8
7.	Upper monumental sandstone	45
8.	Hard limestone, buff	2½
9.	Lower monumental sandstone, red	78
10.	Massive lumpy limestone (in middle of hill 1 mile northwest of Colores)	20
11.	Reddish soil (rocks concealed)	33
12.	Red sandstone	92
13.	Heavy-bedded limestone, carrying *Spirifer cameratus*	24
14.	Salmon-red sands and fine-grained sandstone	120
15.	Purple limestone	4
16.	Concealed (shale?)	110
17.	Limestone, with crinoid stems	5
18.	Concealed (shale?)	45
19.	Purplish sandy limestone	15
20.	Shale?	50
21.	Purple thin slabby sandy limestone	3
22.	Shale?	15
23.	Purplish slabby sandy limestone	15
24.	Massive shelly cross-bedded purple sandy limestone	25
25.	Concealed; probably red shales and sandstones	90
26.	Purple sandy oolitic limestone	1
27.	Massive red arkose and conglomerate, with ¼-inch pebbles (bottom of Casper formation)	20
	Granite.	
		1,259½

This section exhibits twelve beds of limestone, from 1 to 25 feet in thickness and separated by beds of shale and sandstone. The sandstone beds of the lower portion of the section are prevailingly arkosic and locally conglomeratic. The limestones are usually crystalline, in many places sandy, and range from purple to white in color. The purple limestone members near the base of the formation are a noticeable feature for many miles along the Laramie Mountains, and usually they yield the lowest fossils. The heavy bed of limestone in the lower middle portion is especially conspicuous in Cheyenne Canyon, where it lies on bright-red sandstone in turn underlain by gray sandstones more than 100 feet thick. North of Laramie and to some extent in other places the top member of the formation is a coarse gray sandstone, 30 to 50 feet thick, which constitutes the

A. CROSS-BEDDED SANDSTONE OF CASPER FORMATION AT RED BUTTES, WYOMING.



B. PULPIT ROCK, SOUTH OF LARAMIE, WYO.

lower mountain slopes rising out of the red-shale valley. East of Laramie this sandstone is overlain by a 6-foot bed of limestone which is extensively quarried. It extends some distance to the south. South of Gilmore Canyon the purple tint of the limestones is stronger, their sandy character is more pronounced, and the beds are thinner. This change is such that although about Laramie and northward limestones predominate, to the south, in the vicinity and west of Tie Siding, red shale and arkosic sandstone are the prevailing rocks. The limestones do not disappear, however, but most of them persist as thin beds to the Boulder Ridge fault. About 250 feet from the top of the formation there is a sandstone member about 200 feet thick divided into three ledges by thin limestone beds. This sandstone is fine grained, massive, cross-bedded, light red to salmon colored, and weathers into fantastic forms or monuments. About Red Buttes, at the end of Boulder Ridge, and in the "mushroom gardens" along Sand Creek, these monuments are especially numerous, occurring in extensive groups, some features of which are shown in Plates II, *B*, and V.

The formation thins to the southwest, the Pulpit Rock section showing only about 500 feet of the formation, or 500 feet less than in Gilmore Canyon, and with this decrease in thickness the limestone members diminish in number and thickness. The following sections show the principal features:

Partial section of red beds near Pulpit Rock, on Sand Creek, at Colorado state line.

		Feet.
Wavy gypsiferous limestone	Chugwater	2
Red shales with aragonite	Chugwater	100
Wavy gypsiferous limestone (Forelle?)		4
Light-buff sandstones and shales		100
Flaggy to massive light-colored sandstones		30
Limestone (thins out)		1
Massive fine-grained red monumental sandstone		40
Shale, arkosic sandstone, and conglomerate		40
Heavy blocky limestone; forms slope in this vicinity		5
Sandstone, arkose, and conglomerates		170
Sandstone		5
Arkosic sandstones and conglomerates		80
Limestone		2
Arkosic sandstones and conglomerates		25
		604

Section of red beds at Red Mountain. [a]

	Feet.
Chugwater:	
Red sandstone and shale	675
Gray wavy quartzite (gypsiferous limestone?)	5
Red shale and sandstone	100
Red clay and gypsum with aragonite crystals	20
Solid gypsum	50

[a] Condensed from Knight's section, op. cit., pp. 418-419.

Section of red beds at Red Mountain—Continued.

	Feet.
Forelle:	
Fossiliferous rock	4
Casper:	
Gray sandstone	20
Red sandstones	15
Interval, not more than	50
Red sandstone	152
White to red shaly sandstone	96
Reddish fine-grained monumental sandstone	52
Shelly drab limestone	$2\frac{1}{6}$
Red sandstones and conglomerates	124
Red to gray bedded sandstone, with plants	22
Light to red coarse sandstone and conglomerate	166
Drab calcareous sandstone	$1\frac{1}{6}$
Light to red coarse sandstone and conglomerate	86
Granite.	
	$1,640\frac{1}{3}$

The lower portion of this section was measured on Sand Creek near the Pulpit Rock. Another section of the Casper formation, measured on the north face of Red Mountain and reaching to the granite at the southern base of Ring Mountain, is as follows:

Section of Casper formation on Red Mountain.

	Feet.
Fossiliferous impure Forelle limestone (overlain by 67 feet of gypsum at base of Chugwater formation)	1
Buff shale and calcareous sandstone	9
Massive light sandstone	50
White arenaceous shale and a little soft sandstone	55
White, soft massive sandstone	18
White arenaceous shale	20
Red arenaceous shales and thin, flaggy red sandstone	90
Pink to white massive sandstone; some arkose	39
Red shale	6
Sandstone	4
Red shale and sandstone (limestone nodules at base)	161
Concealed red beds—shales, sandstones, and arkose	155
Granite at south base of Ring Mountain.	
	608

In these sections there are only two limestone beds and they are inconstant and impure. The monumental sandstones are not prominent, although they project here and there. Near the crossing of Willow Creek, 2 miles east of Willow Springs, a bed of limestone 1 foot thick lies on conglomerate consisting of rounded quartz, angular feldspar, and more or less rounded limestone pebbles. Across the creek to the east this limestone becomes more massive and sandy and overlies an arkose conglomerate containing masses of nearly pure limestone, apparently concretionary, 5 to 6 feet in diameter and 2 feet thick. This limestone is the second one above the base of the Casper formation in this vicinity. About 1½ miles north of east of the Willow Creek crossing a similar limestone caps the hill and is likewise underlain by coarse arkose containing concretionary limestone. This is the lowest limestone of the Casper formation in this vicinity, the interval to the granite below, 40 to 50 feet, being occupied by coarse arkose.

A few sections near Colores, Wyo., are given below.

Section of Casper formation in railway cut in SE. corner sec. 1, T. 13 N., R. 73 W., 2½ miles south of Colores, Wyo.

	Feet.
Fine-grained salmon-red cross-bedded sandstone	10
Coarse arkose and conglomerate; limestone fragments at base	4
Purplish sandy limestone	2
Shales and sands below.	

Section of Casper formation 600 yards northwest of preceding section.

	Feet.
Conglomerate	4
Terra-cotta clay; pinches out in local unconformity	1
Arkose	4
Cross-bedded red fine-grained sandstone	5
Arkose, conglomeratic	5
Sands and particolored clays	6

Section of Casper formation at high hill 1 mile northwest of Colores, Wyo.

	Feet.
Limestone	5
Fine-grained buff to salmon monumental sandstone	97
Limestone (lumpy limestone of Gilmore Canyon forms bench here)	13
Terra-cotta sandstone, massive, coarse grained in places	45
Reddish sandy shale and shaly sandstone	40

In the ridges near the head of Sybille Creek the Casper formation varies considerably in thickness. In T. 19 N. the limestone is 250 feet thick and is separated from the granite by 20 feet of pink sandstone. Near the north side of the township a good section is shown in Plumbago Canyon. The Casper lies against the schists, which here constitute a band about 1,200 feet in width between the sedimentary rocks and a broad area of coarse granite of a type similar to that occurring near Sherman station on the Union Pacific Railroad. The schists, mostly dark hornblendic rocks, strike N. 15° E. and dip nearly vertically to the west. Interlaminated are five beds of marble, three of which are 10 feet each in thickness and the other two 15 feet each. They are all highly crystalline and the easternmost bed is very coarse grained. In the Casper the lowest bed of limestone dips parallel to the lamination of the schists, the second bed dips 55° W., the third 20° W., and the fourth and all above, 10° W. It seems likely from the shattered character of the lowest bed of the Casper and the fractured condition of the next limestone bed above that there is at this locality a plane of movement at the junction of the sedimentary and the crystalline rocks.

Section of Casper formation in Plumbago Canyon, Wyoming.

	Feet.
Red beds.	
Limestone and shale interbedded	40
Limestone, heavy bedded	20
Salmon-colored massive sandstone	40
Shaly limestone	50
White limestone	25
Shales with limestone interbedded	100
Limestone	10
Shaly limestone	20
Limestone, fractured	20
Shaly limestone	70
White fine-grained limestone	30
Schists.	

In T. 20 N. the base of the Casper formation is faulted out for some distance and only 80 feet of limestone remain, overlain by alternations of white sandstone and limestone. There is a bed of coarse reddish sandstone at the top, overlain by Chugwater red beds. Sandstone appears again under the limestone just east of the road crossing in T. 21 N. The upper sandstone is a prominent feature in and north of T. 23 N. It is spread out widely by the anticline north and northwest of Boswell Spring, but is buried under Tertiary deposits for some distance in the region west of Garrett. Where it reappears to the north it consists of 100 feet of hard sandstone, in large part quartzitic, which rises in a line of prominent knolls extending northward from sec. 18, T. 25 N., R. 74 W., to Marshall. The underlying limestone rises in a line of ridges parallel to these knolls; it is about 200 feet thick and is separated from the granite and schists by a few feet of brown sandstone.

In the region east of Little Medicine post-office the Casper formation consists mostly of limestone lying on a small amount of sandstone and overlain by brown and gray sandstones. In one prominent ridge near the head of the south prong of Little Medicine Bow Creek the lower beds of limestone for 100 feet contain numerous cherty layers and are separated from the granite by 30 feet or more of red shale merging down into a foot or two of sandstone. These rocks strongly suggest the Amsden formation of the Bighorn Mountains, which is separated from the Chugwater red beds by the Tensleep sandstone.

Erosion and weathering of limestone slopes.—The monuments and "mushroom gardens" formed by the erosion of the massive sandstones of the Casper formation have already been mentioned. The long, gentle, smooth grassy surfaces presented by dip slopes of various beds of the limestones and sandstones form a characteristic feature of the western slope of the Laramie Mountains from Laramie to Tie Siding. They are interrupted here and there by monuments of bright-red sandstone. In the vicinity of Gilmore Canyon these slopes are capped by the 2½-foot layer of limestone (No. 8 in section on p. 14) that lies between the two beds of monumental sandstones. It seems remarkable that a stratum so thin and of such soluble material as limestone should have controlled erosion to the extent here shown. The stratum which forms the wide lower slopes a mile north of Colores is the limestone (No. 10 in the Gilmore Canyon section, p. 14) coming just beneath the lower monumental sandstone. This limestone is 13 feet thick in the vicinity of Colores.

Paleontology and age.—The limestones and calcareous sandstones of the Casper formation have yielded but few fossils, though sparse faunas are found here and there. From the 24-foot bed of limestone (No. 13, p. 14) in Gilmore Canyon only a single *Spirifer cameratus* was obtained, but the 8-foot bed of limestone (No. 6, p. 14) yielded an abundant fauna of the following species determined by G. H. Girty:

Derbya? sp.	Euphemus sp.
Aviculipecten occidentalis.	Bellerophon crassus.
Aviculipecten 2 sp.	Soleniscus hallanus?
Myalina permiana?	Murchisonia aff. M. terebra.
Pleurophorus? sp.	Tainoceras occidentale.
Schizodus sp.	Nautilus sp.
Schizodus meekanus.	Orthoceras sp.
Patellostium montfortianum.	Ammonoid indet.

Doctor Girty regards these species, taken as a whole, as very closely related to and many of them probably identical with those from the upper part of the Pennsylvanian series in the Kansas section.

From limestones in the middle of the formation on the slopes of Laramie Mountain 20 miles north of Laramie were obtained *Productus semireticulatus*, *P. cora*, *Archæocidaris* sp., and *Pinna* sp. (determined by Doctor Girty), all of Pennsylvanian age. In the upper limestone 2 miles east of Laramie *Bellerophon* sp. was found, and in the lowest limestone on the mountain slope 6 miles east of Laramie occur *Meekella striaticostata*, *Spirifer cameratus?*, and *Bellerophon* sp. In the upper limestone a mile north of Satanka *Orthotetes* sp. occurs in abundance. In the lower limestones on Gilmore Canyon 8 miles southeast of Laramie *Spirifer cameratus* was obtained.

Arnold Hague, of the Fortieth Parallel Survey, reported Pennsylvanian fossils from localities on Sybille Creek, Cheyenne Pass, and at a point 5 miles northwest of Sherman.[a] The first locality was in

[a] Hague, Arnold, and Emmons, S. F., U. S. Geol. Explor. 40th Par., vol. 2, Descriptive geology, 1877, pp. 76–77.

200 to 300 feet of limestones about 200 feet above the granite; the second was at about the same horizon; and the third was in the limestone which lies on a thin mass of basal red sandstones.

A few fossils obtained from basal beds of the Casper formation 10 miles southeast of Little Medicine post-office were determined by Doctor Girty as *Spirifer centronatus*, *S. cameratus?*, and *Straparollus utahensis*, which are regarded as Mississippian in age. The rocks are cherty limestones lying upon red shales strongly suggestive in appearance of the Amsden formation of the Bighorn Mountains.

Correlation.—From the general composition and stratigraphic relations of the Casper formation it is believed to represent the Amsden and Tensleep formations of the Bighorn region, the Minnelusa formation of the Black Hills, or the Hartville limestone of the Hartville uplift. The presence of a small amount of basal cherty limestone and red shales with Mississippian fossils to the north is in accord with this correlation, although these rocks probably do not extend southward to Laramie. In the greater part of the region the upper beds of the formation are massive buff to white sandstone closely similar to the Tensleep sandstone.

FORELLE LIMESTONE.

The name Forelle is proposed for the limestone which outcrops along the west slope of the Laramie Mountains to a point beyond Red Buttes through Tps. 14 to 16 N., and which also appears at Boswell Spring and near the head of Sybille Creek. In this outcrop zone the limestone, which ranges in thickness from 4 to 20 feet, gives rise to a low ridge lying a short distance west of the main slope. The shallow valley intervening is due to the presence of the Satanka shale, 200 feet or more thick, which underlies the limestone. The outcrop is interrupted by detritus-covered slopes in Tps. 17, 18, 19, 20, 21, and 22 N., but it is almost continuous from the north side of T. 16 N. (sec. 2) to Sportsman Lake. It passes 2 miles east of Laramie a short distance west of the great springs and crosses the railroad at Forelle and Red Buttes. In sec. 11, T. 16 N., R. 73 W., the limestone is fossiliferous and in part highly gypsiferous. A bed of pure gypsum occurs a short distance below; in a near-by pit in sec. 2 it was found to be 10 feet thick. In the cut just south of Forelle, where the limestone is well exposed, it is heavily bedded and nearly 20 feet thick. To the south, near Red Buttes and beyond to Sportsman Lake, the rock becomes gypsiferous and ranges from massive to thinly laminated in structure. In places it is brecciated. Several beds occur, some of which give place to shale, but there is always one bed or more in the section. At the plaster mill a mile south of Red Buttes the underlying red shales contain two beds of gypsum about 25 feet apart. The lower bed, 15 feet thick, is now worked and the other, 10 feet thick, was formerly worked.

The limestone is hidden by alluvium in the flat extending from Sportsman Lake to and up Lone Tree Valley, but an outcrop on Antelope Creek near the center of sec. 16, T. 13 N., R. 74 W., is believed to be the same bed. It contains the same fossil (*Myalina perattenuata*) that occurs north of Laramie. This bed outcrops along the west side of Sand Creek, where the lower red shales are absent and the limestone lies directly upon sandstones. Apparently it is the Forelle limestone that immediately underlies the 67-foot gypsum bed in Red Mountain and yields the numerous fossils discovered by W. C. Knight.[a] On the slopes 2 miles south of Ring Mountain the limestone under the gypsum is thin, but yields distinctive fossils.

At Boswell Spring the Forelle limestone rises in a short, low ridge. It is 3 feet thick, impure, pink in color, and lies upon red slabby sandstone merging downward into red shales which underlie a valley extending eastward to slopes of gray sandstone. On Sybille Creek it is 4 feet thick and lies on about 125 feet of red shale.

In the Laramie-Red Buttes area the Forelle limestone contains *Myalina perattenuata* and fragments of other species.

The supposed Forelle limestone just below the gypsum 2 miles south of Ring Mountain afforded great numbers of *Aviculipecten occidentalis*, *Myalina perattenuata*, *Allerisma terminale*, and *Schizodus compressus*.

The limestone believed to represent this bed in the Red Mountain section consists mostly of casts and impressions of fossils which were discovered by Knight in 1902.[a] According to Doctor Girty they comprise the following:

Solenomya n. sp.	Myalina perattenuata.
Deltopecten manzanicus.	Pleurophorus aff. P. taffi.
Deltopecten coreyanus?	Dentalium canna.
Schizodus meekanus.	Orthonema? sp.

This fauna is regarded as late Pennsylvanian or possibly equivalent to the lowest limestones of the so-called Permian of Kansas. If it were not for this evidence the beds might be regarded as a portion of the Chugwater formation, for near Laramie and Red Buttes the stratigraphic succession is suggestive of Minnekahta limestone lying upon red shale of the Opeche formation. The Minnekahta limestone occurs on the east side of the Laramie Mountains and in the Black Hills and contains Permian fossils.

The Forelle limestone may represent the Embar formation of the Owl Creek[b] and Bridger Mountain ranges.

[a] The Laramie Plains Red Beds and their age: Jour. Geology, vol. 10, 1902, p. 419.

[b] Darton, N. H., Geology of the Owl Creek Mountains: Senate Doc. 219, 59th Cong., 1st sess., 1906, p. 17.

SATANKA SHALE.

The Satanka red shale lies between the Forelle limestone and the Casper formation in the Laramie region. It is named from Satanka siding, which is situated a short distance east of its outcrop zone. At the mouth of Gilmore Canyon its thickness is 232 feet, and the rock is sandy red shale with thin layers of soft red sandstone, all closely similar to much of the Chugwater formation. The Satanka shale outcrop is generally marked by a shallow valley at the foot of the long sandstone or limestone slopes of the mountains, with a low but distinct ridge of Forelle limestone on its west side. It outcrops almost continuously from T. 17 N. past Laramie and Red Buttes to Sportsman Lake, but on some of the divides it is covered by high terrace deposits and talus. The shale is absent in the Red Mountain region, where the Forelle limestone lies directly on light-colored sandstones believed to be at the top of the Casper formation. It is possible, however, that these sandstones represent the Satanka shale.

Local deposits of gypsum occur in the Satanka shale at Red Buttes. At the plaster mill 2 miles south of that place one bed is 15 to 20 feet thick, and another 25 feet above is 10 feet thick. The upper bed was struck again half a mile farther north, near the Union Pacific Railroad. A 10-foot bed of gypsum was found in the upper part of the shales in a pit in sec. 2, T. 16 N., R. 73 W.

No fossils were found in the Satanka shale, but its Pennsylvanian age is indicated by the occurrence of fossils of that series in the overlying and underlying formations.

TRIASSIC (?) SYSTEM.

CHUGWATER FORMATION.

Character and distribution.—Extending along the foot of the west slope of the Laramie Mountains there is a broad outcrop zone of red shales and soft red sandstones, which undoubtedly represent the Chugwater formation of other regions. The brilliant red color renders the formation a conspicuous feature in many portions of the area. The outcrop passes through Laramie and extends southward past the north end of Boulder Ridge for some distance into Colorado.

In the southern portion of the Laramie Basin the formation consists of the upper half of the "Red Beds" of former writers, but from Laramie northward it lies upon sandstones and limestones. It is extensively exhibited about Red Mountain, which takes its name from the prominent exposures on its north slope. Small areas appear in the faulted zone in Jelm Valley and along the southeast side of Sheep Mountain. It is well exhibited near Boswell's ranch on Laramie River, at the Colorado state line. Narrow zones of outcrop of the steeply dipping beds appear on either side of the Centennial Valley, extending northward to the fault which cuts off all the formations at the north end of that valley. The formation is brought to the surface by the anticlines north and east of Medicine Bow and Rock Creek, covering considerable areas in a broad belt extending from the foot of Como Bluff eastward past Boswell Spring and also in the slopes of Flat Top Ridge. It is exposed in the Freezeout uplift and in wide outcrops on and near Sheep Creek in the vicinity of the mouth of Mule Creek. Three miles southeast of Arlington reddish shales outcrop in the south end of a foothill of the Medicine Bow Mountains, but the exposure is so small that it could not be determined whether the beds were Chugwater or Casper. In the upper portions of the valleys of Little Medicine Bow and Bone creeks the formation is buried under Tertiary deposits, and in the vicinity of Laramie it is extensively hidden by Quaternary sands and gravels.

Local features.—The formation consists mostly of red shales and fine-grained red sandstones, with a subordinate amount of lighter colored sandstones, thin beds of limestone, and deposits of gypsum. The gypsum beds are especially thick and prominent in the Red Mountain neighborhood. The fine-grained massive sandstones weather with rounded outlines, especially where the beds are horizontal, and in places they rise in monuments, one of which near Steamboat Lake has suggested the name of that body of water. (See Pl. V, *B*.) In many other localities where the beds dip steeply the outcrop of the sandstones presents ragged ledges of considerable prominence. In the southern portion of the Laramie Basin the formation is so largely covered by the Quaternary deposits that complete sections are rare, but one exposed in the north face of Red Mountain is believed to comprise all the beds lying between the fossiliferous limestone (Forelle) underlying the gypsum and the base of the typical Morrison.

Section of Chugwater and overlying beds in Red Mountain, Wyoming.

		Feet.
Morrison:		
Shale with green nodules		28
Limestone	Morrison fossils	1
Blue shale	Morrison fossils	50
Limestone	Morrison fossils	2
Blue shale		36
Chugwater:		
Light sandstone		12
Terra-cotta to blue shale		20
Soft sandstone or sandy shale		10
Terra-cotta shale		17
Light-buff soft massive sandstone		30
Terra-cotta, blue, and green shales		65

Section of Chugwater and overlying beds in Red Mountain, Wyoming—Continued.

	Feet.
Chugwater—Continued.	
Light shale	22
Heavy, flaggy light to buff sandstone and light shales	30
Pink massive fine-grained sandstones	24
Reddish salmon-colored sandy shales	35
White flaggy sandstone and red shales	45
Massive, cross-bedded, fine-grained, monumental salmon sandstone	15
Flaggy white sandstone and reddish shales	20
Massive, cross-bedded, fine-grained, monumental, salmon sandstone	65
Red shales and red flaggy and massive sandstones	450
Red gypsum, nearly pure	6
Red shale	35
Gypsum	3
Red shale	10
Gypsum	4
Red shale	55
Fine banded wavy gypsiferous limestone	5
Red sandy shale (aragonite crystals)	88
Gypsum, pure, massive	67
	1,133

The upper limit of the formation is placed arbitrarily at the base of the blue shale below the lowest limestone containing Morrison fresh-water fossils. This classification includes in the upper part of the Chugwater about 200 feet of an alternation of terra-cotta, blue, and buff shales and light-colored sandstones which are not typical and are absent in the region farther northeast; but they appear more likely to belong in the Chugwater than in the Morrison formation. The gypsiferous member at the base of the Chugwater formation is 273 feet thick in this section and consists of alternations of gypsum, gypsiferous limestone, and red shales, with the massive bed of pure gypsum 67 feet thick at the base. In the red clay 20 feet above the heavy gypsum bed there are numerous crystals of aragonite in hexagonal prisms, usually short prismatic to tabular, and in penetration twins of the tabular form. According to Knight they are pseudomorphs after hanksite. Above the gypsiferous measures are 450 feet of typical red beds consisting of alternations of red shales and red flaggy sandstones. Next above are 378 feet of beds consisting largely of massive fine-grained salmon-colored sandstones with a minor proportion of red shale. These sandstones weather with rounded outlines and in their erosion forms resemble the monumental sandstones of the Casper formation. (See Pls. II, *B*, and V.)

In the slopes adjacent to Medicine Bow River 3 miles north of Medicine Bow, where the formation has an average dip of 10°, the thickness is about 1,300 feet. At the top are about 10 feet of red shales, below which are 20 feet of gray slabby sandstone, 100 feet of red sandy shales, 8 feet of gray slabby sandstone, 30 feet red shale, 2 feet of gray slabby and ripple-marked sandstone, 3 feet of red shales, 8 feet of soft gray sandstone, and a thick succession of red sandy shales and soft red sandstones. Toward the base are several thin-bedded sandstone members 5 feet or less in thickness.

Gypsiferous member.—On Sand Creek the gypsum measures are not prominent, but ledges of this mineral from 2 to 4 feet thick, associated with and locally replaced by gypsiferous limestone, crop out on the red point north of the North Park road crossing and at localities east and south of that place. At the bottom of these exposures there is a wavy gypsiferous limestone which is supposed to represent the Forelle. This assumption is strengthened by the occurrence of aragonite crystals on the hill slopes above the limestone in a position similar to that which they occupy in the Red Mountain section. A mile southeast of Sportsman Lake there is an outcrop of gypsum, apparently lying above wavy gypsiferous limestone that can be traced northward with certainty into the Forelle limestone, which crosses the railroad at Forelle. At a point northwest of Forelle and west of the line of outcrop of the Forelle limestone a well 333 feet deep is reported in the red beds and gypsum measures that doubtless lie above that limestone.

In the Centennial Valley the gypsum measures are represented by a thin gypsiferous limestone bed, separated from supposed Forelle limestone by red shales. They are overlain by alternations of red shale and soft red sandstones. The upper part of the formation includes the monumental sandstones as in other portions of the region.

Upper limestone.—In the northern part of the Laramie Basin region there is a thin but conspicuous bed of limestone in the upper part of the Chugwater formation. It thickens to the west and is conspicuous in the Freezeout uplift, where it lies a few feet below the Sundance formation.

Age.—The age of the Chugwater formation is not definitely known, but has been supposed to be in part at least Triassic. In other portions of Wyoming it includes in its lower portion a limestone known to be Permian[a] in age, and in the Bighorn region limestone 150 feet below the top of the formation contains supposed Permian fossils. The fact that the formation is underlain by similar red beds of the Casper formation in the southern portion of the Laramie Basin throws no light on its age, for in this area red beds may have continued to be deposited from Pennsylvanian through Permian and into or through Triassic time.

---

[a] In the sense in which that term has been used in the Mississippi Valley.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

Occurrence and relations.—The Sundance formation is extensively developed in the northern half of the area to which this report relates, but it thins out and disappears somewhere west of McGill. It is exposed in the uplifts east and north of Medicine Bow, in the Freezeout Hills, and in the ridge of which Bootheel Butte is one of the summits.

The Sundance formation in this region presents the features which are characteristic of it in the greater part of Wyoming and in the Black Hills uplift. The lower beds are predominantly sandy; the upper part consists largely of green shales with hard layers carrying large numbers of fossils. The most extensive exposure is in the anticline east of Medicine Bow, where the formation is 119 feet thick and the strata are as follows:

Section of Sundance formation in Como Ridge, 6 miles east of Medicine Bow, Wyo.

	Feet.
Morrison shale.	
Limestone and shale	15
Massive disintegrated sandstone, in part shaly	10
Drab shale with a few lumps of brown limestone	30
Buff shaly sandstone	5
Yellow sandy shale with belemnites	42
Buff shaly sandstone	5
Yellow shale (lying on Chugwater red beds)	12
	119

In the ridge 2 miles north of Medicine Bow the lower half of the formation is a massive buff sandstone with 8 feet of red shale about 100 feet above its base and a 2-foot bed of red shale a short distance higher.

Although there is a long time hiatus between the Sundance and Chugwater formations the unconformity between them is not marked by discordance of dip or conspicuous erosion, and in places it is difficult to draw the line between them. This is probably due to the derivation of the material in the upper formation from the one below. The upper limits of the Sundance are similarly ill defined. A section in the eastern side of the Freezeout Hills near Dyer's ranch, given by W. N. Logan,[a] is as follows:

[a] Kansas Univ. Quart., vol. 9, 1900, pp. 111, 113.

Section of Sundance formation in Freezeout Hills, Wyoming.

		Feet.
15.	Purplish clay with sandy inclusions; has sandy limestone layer near base filled with fossils	40
14.	Greenish sandstone, thinly laminated	2–5
13.	Purplish fossiliferous clay with many lime nodules filled with fossils	20
12.	White sandy clay; saurian remains	4
11.	Sandy clay with brown concretions (apparently no fossils); green sandstone layer near middle	6
10.	White sandy limestone, in thin layers (fossils)	½
9.	Sandy red clay	10
8.	White fissile sandstone	6
7.	Shale, reddish, changing to purple	4
6.	White sandstone, moderately hard	½
2–5.	White sandstones separated by two layers of red clay	1
1.	Red clay of Chugwater formation.	
		94+.

Possibly beds 2 to 9 belong in the Chugwater formation and perhaps the unfossiliferous portion of bed 15 may be a part of the Morrison.

Fossils.—In the section given above, Logan reports the following fossils:

Bed 10, *Pseudomonotis curta;* bed 12, remains of *Ichthyosaurus* and *Plesiosaurus;* bed 13, abundant *Belemnites densus* throughout, and in the concretions *Pinna kingi, Pinna* sp., *Cardioceras cordiforme, Avicula beedei, Astarte packardi, Pentacrinus astericus, Tancredia bulbosa, T. magna, Lima lata, Goniomya montanaensis, Avicula mucronatus, Pleuromya subcompressa, Cardinia wyomingensis, Pseudomonotis curta, Belemnites densus*, and *B. curtus*, and also remains of plesiosaurs and ichthyosaurs; bed 14, *Camptonectes bellistriatus, C. extenuatus, Ostrea densa,* and *O. strigilecula;* in a sandy limestone in base of bed 15, *Pentacrinus astericus, Asterias dubium, Pseudomonotis curta, Avicula mucronatus,* and *Ostrea strigilecula.*

The following fossils occur in the limestone layers in the Sundance formation on Como Ridge and in other outcrops to the north and west: *Pseudomonotis curta, Pleuromya newtoni, Goniomya montanaensis,* an echinoid spine, and *Belemnites densus.*

It is reported that belemnites have been found a mile or so southeast of Morgan, but no traces of the formation were found in that vicinity.

CRETACEOUS SYSTEM.

MORRISON FORMATION.

Distribution and general relations.—The outcrop of the Morrison formation extends along the east side and around the south end of the Laramie Basin, and it also appears in the uplifts east and north of Medicine Bow, east of Rock Creek, in the Freezeout Hills, and in the line of ridges of which Bootheel Butte is a part. For a large portion of its course, however, especially between Rock Creek and Laramie and in the Little Medicine Bow basin, it is covered by Tertiary and Quaternary deposits. Two narrow zones of outcrop extend along both sides of the Centennial Valley and the formation shows for

2 miles along the east slope of the Jelm Valley just east of Jelm. A small area is faulted to the surface just east of Sheep Mountain, 3 miles north of Woods Landing. Some of the most extensive exposures are west and southwest of Red Buttes, at Red Mountain, west of Downey Lakes, on the east side of Centennial Valley, along the north face of Como Ridge east of Medicine Bow, along Little Medicine Bow Creek near latitude 42°, and in the ridge of which Bootheel Butte is one of the summits. There are large exposures in the Freezeout Hills, of which only the eastern margin extends into the area treated in this report. In the southern half of the Laramie Basin the Morrison lies upon the Chugwater red beds, but to the north the Sundance formation intervenes.

Character.—The Morrison deposits are mainly hard clay or massive shale varying in color from pale greenish to maroon and having a peculiar chalky appearance. The prevailing tint is pale olive green. Thin beds of drab limestone and a few beds of light-colored sandstone are included. At some places there occur also concretionary masses, 2 inches or less in thickness, of olive-green to dark-green brittle siliceous rock. A section of the formation in Como Ridge is as follows:

Section of Morrison formation in Como Ridge east of Medicine Bow, Wyo.

	Feet.
White, massive sandstone, conglomeratic (Cloverly).	
Bluish to greenish shales	50
Limestone, lumpy	1
Bluish to olive-green shales	30
Limestone, lumpy	1
Blue and red shale	120
	202

In Red Mountain the formation is 128 feet thick and consists mainly of pale bluish shale which in the upper beds contains green nodular masses. At 36 feet above the base there is a 2-foot layer of limestone, and at 88 feet above the base a 1-foot limestone layer containing fresh-water fossils. At the base of the formation lies a series of light-colored sandstones and terra-cotta and bluish shales which may possibly represent the marine Jurassic, but, as they contain no fossils, they have been provisionally placed in the Chugwater.

Section of Morrison formation on east slope of ridge west of Downey Lakes, Wyoming.

	Feet.
Coarse sandstones and shales (Cloverly).	
Drab to olive-green shale	30
Soft, coarse-grained, disintegrated sandstone with calcareous matrix containing teeth and bones	6
Drab to blue shales	15
Nodular limestone	1–2
Blue shales	50
Limestone	2
Concealed; probably blue shale	30+
	135+

On the east side of the Centennial Valley the formation presents features similar to those in Red Mountain, containing two thin beds of limestone, but the thickness is more than 300 feet.

The formation outcrops on the west bank of Laramie River just north of the bridge a mile northwest of Laramie in a low mound capped by terrace gravels. The beds comprise 3 feet of dark shales at the base, then 20 feet of soft, massive light-colored sandstones, and finally 10 feet of gray shales with several thin slabby limestone layers (one of which is pebbly) and a thin layer of gray sandstone. Exposures of moderate extent appear in the slopes 1½ to 2 miles south-southwest of Howell station. The lower beds are soft, massive buff sandstones. These are overlain by gray and greenish-gray massive shale or clay with thin cherty limestone and sandstone layers. One of the latter is 2 to 3 feet thick. At the top are very dark shales which have been prospected for coal. They are overlain by coarse sandstones at the base of the Cloverly formation.

In the exposures west of McGill a 2-foot bed of limestone is included in the formation.

In the Freezeout Hills the Morrison formation presents its usual characteristic features. According to a description by W. N. Logan[a] it consists of clays and sandstones and its limits are somewhat uncertain. A section near Dyer's ranch given by Logan is as follows:

Section of Morrison formation in Freezeout Hills, Wyoming.

	Feet.
24. Grayish-white sandstone (may be basal Cloverly)	50
23. Drab clay, with saurian remains	70
22. Brown to bluish-gray sandy limestone, with molluscan fossils.	1
21. Bluish-green clay, with very small concretions; dinosaurs and mollusks	30
20. Fissile brownish sandstone; no fossils	4–5
19. Drab clay; dinosaur remains	30–40
18. Sandstone, grayish to light brown, in part cross-bedded, on 2½ feet of conglomerate; fossil wood and cycads	10–20
17. Purplish to greenish clay, with dinosaurs in upper part	60
16. Grayish-white sandstone, fine grained, in part cross-bedded, moderately soft	10–125

The lowest bed in this section is only 10 feet thick at Dyer's ranch, but increases to 125 feet a few miles south. It is separated from beds carrying Sundance fossils by 40 feet of purplish clays which may belong to the Morrison formation.

Fossils and age.—Large numbers of dinosaurian bones have been obtained from the Morrison formation, notably from the extensive bone quarries near "Bone Cabin," in the northeastern portion of the Freezeout Mountains. They comprise *Brontosaurus, Morosaurus, Ornitholestes, Laosaurus, Camptosaurus, Dryosaurus, Diplodocus, Stegosaurus,* and *Allosaurus,* the two last mentioned occurring in

[a] Op. cit., pp. 113–115.

the upper drab clay. Collections have also been made from the north slope of Como Ridge, from the outcrops 2 miles west of Steamboat Lake, and from the lower portion of the valley of Bone Creek. Bones have been found also at a point 2 miles east of Red Mountain, at several localities in Colorado a short distance south of the state line, in the slopes just west of Downey Lakes, and across Laramie River east of Jelm post-office. The drab, brittle, impure limestones occurring in the Morrison contain numerous remains of fresh-water mollusks which are usually of very small size. Fossil algæ are not observed in the limestones in the Laramie Basin. Collections of mollusks made from various points have been identified by T. W. Stanton, as follows: West of Downey Lakes, in the NW. ¼ sec. 15, T. 13 N., R. 75 W., *Unio baileyi*, *Valvata?*, and *Limnæa;* at Riverside ranch, in the NE. ¼ sec. 10, T. 13 N., R. 76 W., *Planorbis veternus*, *Valvata scabrida*, *Vorticifex stearnsi*, *Viviparus?;* on the ridge 3 miles south of Hutton Lakes, in the SW. ¼ sec. 32, T. 14 N., R. 74 W., *Planorbis veternus*, *Valvata scabrida*, *Vorticifex stearnsi*, *Limnæa;* on the road west of Homer's ranch, in the NW. ¼ sec. 11, T. 14 N., R. 74 W., *Viviparus* n. sp., "a large form wholly unlike anything previously reported from the Morrison;" on Como Ridge, in the SW. ¼ sec. 9, T. 22 N., R. 77 W., *Unio* sp., *Valvata scabrida*, and *Limnæa accelerata.*

In the thin layer of sandy limestone in the Morrison formation in the Freezeout Hills (bed 22, p. 29) Logan reports molluscan fauna as follows: *Unio knighti*, *U. willistoni*, *U. baileyi*, *Valvata leei*, and *Planorbis veternus.* The two last named occur also in bed 21. Numerous cycads and pieces of fossil wood and a fragment of a hollow-boned dinosaur are reported from bed 18 in the same section.

The dinosaurian remains in the Morrison formation have been regarded as Jurassic in age, but some eminent paleontologists now believe that they are early Cretaceous. As the stratigraphic relations in some regions sustain this view, the formation is provisionally assigned to the Cretaceous.

CLOVERLY FORMATION.

The Cloverly formation underlies a wide area in the Laramie Basin. Its outcrop zone extends all along the east side, crosses the south end of the basin, and follows an irregular course in the area of cross flexures west of McGill and north of Medicine Bow. It passes under the Tertiary deposits west of Marshall, but reappears in a small knoll 2 miles west of Little Medicine. For many miles along the west side of the basin from Laramie River northward it is dropped far below the surface by a great fault. There are prominent exposures west of Red Butte and in the ridges lying between Downey Lakes and Jelm Mountain. Small areas cap Red Mountain and the ridge next east, and the formation is exposed at points 2 miles west and

6 miles northwest of Laramie. There are extensive exposures in the anticlines east and north of Medicine Bow, in the Freezeout Hills, and in the Bootheel Butte ridge west and southwest of Marshall. The crest and south slope of Como Ridge consist mostly of this formation. It forms a distinct hogback ridge on each side of the Centennial Valley and occurs in the steep-sided syncline in Jelm Valley near Jelm post-office.

The Cloverly formation consists of sandstones and clays representing the formation which has usually been referred to as "Dakota" sandstone (Lakota, Fuson, and Dakota formations). Its thickness in the Laramie Basin rarely exceeds 200 feet and ordinarily the amount is considerably less. It consists nearly everywhere of two sandstones separated by buff and purplish sandy clays. The sandstones, especially the lower one, are as a rule locally conglomeratic, with pebbles of varicolored cherts and jasper. The lower sandstone is the most prominent member topographically, giving rise to a notable hogback range in various portions of the region. This feature is especially conspicuous in the ridge extending west of Red Buttes and west and southwest of the Downey Lakes, Como Ridge, the Freezeout Hills, the ridge south and west of Marshall, and a prominent knob in the west side of T. 24 N., R. 76 W.

There is an extensive and complete exposure of the Cloverly formation in the anticline on the south side of Hutton Lake. The dip is nearly vertical and the sandstone runs out into the lake in a prominent point. The following beds appear:

Section of Cloverly formation on south side of Hutton Lake, Wyoming.

	Feet.
Gray to light-buff sandstone, cross-bedded below, softer above	70
Coaly shale	1½
Sandy clays, greenish buff below, black in middle, and gray near top	30
Sandy shales with two cherty layers	20
Clays, shales, and sandstones, part dark gray, part purplish	40
Sandstone, fine grained, soft, with harder and coarser layers	40
Sandstone, light gray, massive and cross-bedded, in part conglomeratic	35
Morrison formation.	

Section of Cloverly formation near preceding section.

	Feet.
Bedded white disintegrated sandstone, shaly at top, slickensided between the strata	70
Drab shale	30
Massive white fine-grained disintegrated sandstone	40
Dark-brown to black nodular chert	3
Light-colored shales and sandstones	70
Massive white to light-buff coarse sandstone, crystalline cement with "patchy" reflection (calcite), a very little conglomerate	28
Particolored shales of Morrison	60+

These sections show the variability of the formation within short distances.

At the north end of the Cloverly hogback on the east side of the Centennial Valley, in sec. 18, on Little Laramie River, there is a section in which the formation is seen to consist of 10 feet of massive sandstone, 100 feet of flaggy ferruginous sandstone and shale, and (at the base) 40 feet of massive white sandstone. The basal sandstone is conglomeratic in places. Below this sandstone are 30 feet of ferruginous shales which may belong either in the Cloverly or Morrison formation, and then 300 feet of typical bluish to purple Morrison shales. On the south bank of Laramie River north of Jelm Mountain the Cloverly formation has at the top 25 feet or more of buff flaggy sandstone; then 60 feet of shales, greenish above, buff below, with some layers of flaggy white sandstone; and at the base 23 feet of flaggy buff sandstone. The relation of the basal sandstone to the Morrison formation is concealed by talus. In the hill 2 miles south-southwest of Howell station the formation is only about 50 feet thick, consisting of two massive, coarse, hard sandstones separated by dark shale which has been prospected for coal. In the ridge north and northwest of Medicine Bow the Cloverly formation is 140 feet thick. In the prominent butte on the axis of the anticline north of Bone Creek it is 150 feet thick and consists of three sandstones separated by gray and purplish shales and clays. Northwest of Bootheel Butte the formation appears to consist entirely of hard gray sandstone and the thickness is less than in the region farther south.

BENTON FORMATION.

Distribution and general relations.—A large portion of the Laramie Basin is occupied by the dark shale of the Benton formation. It outcrops at intervals from the foot of Jelm Mountain northeastward past Laramie, through Wyoming station and south of McGill to old Rock Creek station, but owing to the softness of its materials it has been deeply eroded, and it is largely covered by Quaternary deposits. It is extensively exhibited from the Wheatland reservoir westward through Rock Creek and Como Ridge, in the anticlinal ridges north of Medicine Bow, along the east side of Medicine Bow Valley and all around the Freezeout Hills, in the vicinity of the Hutton Lakes, in the hills 1½ miles southwest of Howell station, and in the railroad cuts extending from a point a mile north of Howell to Wyoming. It disappears beneath Tertiary deposits southwest of Little Medicine Bow post-office. Its outcrop extends along both sides of the Centennial Valley and it appears in small areas on Laramie River above Woods Landing and in the slopes west of Red Mountain.

The formation appears to lie conformably upon the Cloverly formation and to be succeeded conformably by the overlying Niobrara formation. In the southern part of the basin the thickness is nearly

700 feet, to judge by the drill hole 2 miles northwest of Hutton Lakes, which began near the top of the formation and reached the Cloverly at a depth of 600 feet. The thickness of the steeply dipping beds in the Centennial Valley is between 500 and 600 feet. Near Rock Creek the formation is about 1,000 feet thick, and the amount increases to 1,300 feet northwest of Medicine Bow.

Character.—The Benton formation consists mainly of gray to black shales, and it lacks the middle limestone member (Greenhorn), which is so characteristic in the Black Hills region and Colorado. About 200 feet above the base is the Mowry shale member, which consists of about 100 feet of hard shales and thin-bedded, fine-grained sandstones, which weather to a light silvery gray color and contain large numbers of fish scales. Owing to its hardness, this member gives rise to ridges of considerable prominence. It is especially conspicuous in the slopes east of Jelm Mountain, east and northeast of Hutton Lakes, southwest of Howell, and in the anticlines near Medicine Bow, old Rock Creek station, and the Freezeout Hills. Near the top of the Benton formation there is invariably a bed of sandstone in many places 20 to 30 feet thick, and toward the bottom there are usually one or more thin beds of sandstone, one of which is several feet thick at Hutton Lake. In the exposure southwest of Howell station the following beds were exhibited: At the base, 200 feet of dark shales, including a 5-foot bed of buff sandstone 45 feet above the top of the Cloverly formation; next above, 100 feet of Mowry shale overlain by 100 feet of dark shales with dark concretions. The upper beds are concealed by Quaternary deposits in this vicinity, but the upper shales are extensively exposed in the long, deep railroad cut a mile north of Howell, and the upper sandstone outcrops in cuts just south of Wyoming station, where it is 30 feet thick. In the slopes 5 miles east of the summit of Jelm Mountain the basal beds below the Mowry member consist of 20 feet of drab, brittle sandy shale, 6 feet of black sandstone, 4 feet of white sandstone, and 145 feet of black shale lying on the Cloverly formation. In a bluff on the south side of Laramie River, 3 miles north-northeast of the summit of Jelm Mountain, the upper beds of the Benton exposed consist of 5 feet of black shale at the top, 27 feet of soft gray heavy flaggy sandstone, 8 feet of interbedded sandstone and shale, and 30 feet of black shale. In the syncline northeast of Red Mountain the lower 110 feet of the formation consists of black shales, which are overlain by 30 feet of yellowish to gray shales and 10 feet of flaggy buff sandstone containing impressions of long, narrow willow-like leaves. On the southeast side of Hutton Lake the lower beds of the Benton are exposed, dipping steeply and lying upon the Cloverly formation. At the base are 100 feet of dark shale with a few thin sandstone layers, then 25 feet of gray sandstone, overlain by 30 feet of dark shale, upon which lies the Mowry member, 100 feet or more in thickness.

A short distance northwest of Medicine Bow the Benton formation presents the following section:

Section of Benton formation northwest of Medicine Bow.

	Feet.
Shale, gray	200
Sandstone, gray, partly slabby	40
Shale, gray	800
Shales, hard, and fine-grained slabby sandstones (Mowry)	75
Shales, mostly dark, weathered brownish, and with thin sandstones in lower part	250
Cloverly formation.	

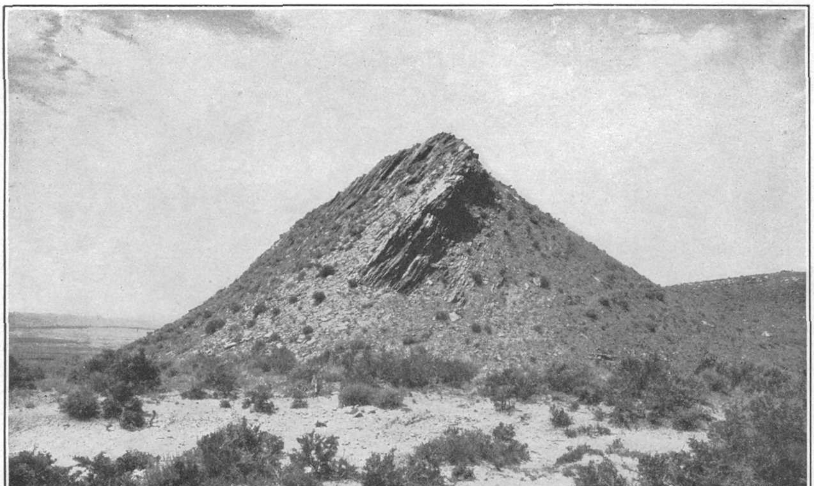
The upper sandstone of the Benton is especially prominent in the Rock Creek district, giving rise to a long sinuous ridge which is very persistent. (See Pl. VI, *B*.) In the vicinity of old Miser station it consists of a 4-foot ledge of buff, massive sandstone. It is overlain by 350 feet of shales and underlain by several hundred feet of dark shales containing a bed of bentonite and black ironstone concretions. Next below these is the Mowry shale. The beds of bentonite, which appear extensively in this vicinity, are persistent features. The thicker one in the vicinity of Miser averages 4 feet in thickness and lies a few feet above the Mowry shale. It is succeeded by 15 or 20 feet of nearly black soft shale, at the top of which are many ferruginous concretions. On the east bank of Sand Creek, near the middle of the north side of sec. 2, T. 13 N., R. 75 W., the bentonite is 4 feet thick and is underlain by 7 inches of soft gray sandstone.

Fossils.—The principal fossils of the Benton formation are the very numerous fish scales in the Mowry shale member and a few fragmentary molluscan remains, fish bones, and teeth which occur at various horizons. In the upper sandstone, near the foot of Jelm Mountain, were found *Inoceramus fragilis*, together with fish teeth apparently of *Ptychodus* and *Lamna*. The upper sandstone also contains *Prionocyclus*, a fossil which is characteristic of the upper portion of the Benton (Carlile) in a wide area of the Rocky Mountain and Great Plains provinces.

NIOBRARA FORMATION.

The Niobrara formation outcrops at intervals from the foot of Sheep Mountain northeastward nearly to Wyoming station, in the hills east of Lake Ione, along the sides of the various flexures east of Medicine Bow, in the Freezeout Hills, and along both sides of the Centennial Valley. A wide outcrop zone extends up the valley of Little Medicine Bow Creek in Tps. 24, 25, 26, and 27 N. Small exposures appear at the south end of Sheep Mountain, in the valley

A. SANDSTONE IN MONTANA GROUP AT PINE RIDGE, NEAR ROCK RIVER STATION, WYO.



B. SANDSTONE IN UPPER PORTION OF BENTON FORMATION, NORTHWEST OF MEDICINE BOW, WYO.

just west of Jelm Mountain, on the slopes 3 miles west of the summit of Red Mountain, and along the roadside 3 miles northeast of the Rock River depot. The outcrop crosses the Union Pacific Railroad just north of Wyoming and at two localities a few miles east of Medicine Bow. In many places the formation is buried beneath later deposits. The most extensive exposures are in the south end of Big Basin, in the east and west portions of The Big Hollow, in bluffs along Laramie River west and north of Hutton Lakes, north and east of Medicine Bow, in the banks of Rock Creek southwest of Rock Creek post-office, on Sheep Creek 2 miles above its mouth, and in bluffs along Little Medicine Bow Creek in T. 26 N.

The formation consists largely of impure chalk rock which weathers to a bright-yellow color and contains large numbers of *Ostrea congesta.* The thickness could not be ascertained satisfactorily, except in the sharp upturn 2 miles northwest of the Union Pacific Soda Lakes, where it is 425 feet, and east of Miser station, where it is about 200 feet. In the middle of the formation there is a deposit of dark-gray shales. The chalk rock is in beds varying from thin layers to slabs an inch or 2 inches in thickness, and locally it is sufficiently hard to give rise to buttes of considerable prominence, as in the west end of The Big Hollow; in bluffs overlooking Big Basin, 5 miles northwest of Laramie; and at Chalk Bluffs, 6 miles southeast of old Rock Creek station. The bright-yellow color of these bluffs renders them conspicuous features.

MONTANA GROUP.

Distribution and general relations.—The large syncline northwest of Laramie is occupied by shales and sandstones of the Montana group. Another smaller area extends along the west side of the valley of Little Medicine Bow Creek north of the uplift of the Freezeout Hills. The group is here composed of two parts. The lower part consists of dark shales representing the greater portion if not all of the Pierre shale. The upper part begins with a prominent bed of sandstone succeeded by sandstones and shale, including beds of coal, and approximately represents the Fox Hills. It is probable that the uppermost beds in the center of the larger basin and along its western margin represent the Laramie formation.

Outcrops of the Montana group are numerous and extensive, except along portions of the valleys of Little Laramie and Laramie rivers and Rock Creek and in some of the intervening divides where there are extensive mantles of alluvium and earlier Quaternary deposits. In the deeper portion of the basin, south of Lookout, the Montana is covered by Tertiary deposits. For many miles along the foot of Medicine Bow and Sheep mountains the group is faulted against the granite and schists.

Character.—The lower part of the Montana consists of 3,000 to 4,000 feet of dark shales with local thin beds of sandstone and numerous nodular sandy concretions. Few of the sandstone beds are more than 5 feet thick and they are separated by 100 to 300 feet or more of dark shales. Toward the top of this lower part there is a thin but prominent bed of hard, nodular sandstone of light-gray color, which is somewhat prominent in outcrops 14 miles west by south of Laramie, 8 miles north-northwest of Laramie, and 3 miles southwest of old Rock Creek station. The upper part of the group begins with a bed of moderately hard gray sandstone about 60 feet thick, which appears prominently in Pine Ridge 2 miles southeast of Rock River station and on the bank of Little Laramie River, in sec. 3, T. 16 N., R. 76 W. It also constitutes part of the high ridge in the northwestern portion of T. 15 N., R. 76 W. Pine Ridge, which is due to this sandstone, is a prominent feature on the railroad 2 miles southeast of Rock River station and for some distance east and west, having the appearance shown in Plate VI, *A*. A sandstone supposed to be this bed and containing some fossil plants crosses Laramie River at the Dunn ranch, in sec. 30, T. 20 N., R. 74 W. Coal is found just above this heavy sandstone in a number of places along the ridge both east and west of the railroad. In the S. ½ sec. 9, T. 20 N., R. 77 W., on the north side of Rock Creek, there are outcrops of a massive sandstone dipping to the northwest and overlain by coal-bearing beds, which appears to be the same as the sandstone of Pine Ridge. A mile farther south, in sec. 21, in the bank of Rock Creek, there are outcrops of coal which dip 5° to 8° S., but this coal apparently is considerably below the sandstone of Pine Ridge. Coal occurs in secs. 4, 8, and 18, T. 19 N., R. 77 W., on Coal Bank Creek, not associated with any prominent sandstone, but probably to be correlated with the coal of Pine Ridge. On Cooper Creek, in the southeast corner of sec. 17, T. 18 N., R. 77 W., a heavy massive buff sandstone appears, dipping 40° E. This dip indicates that the sandstone is considerably below the fossil bed east of Bengaugh's ranch in Cooper Creek Cove and therefore probably at the same horizon as the sandstone of Pine Ridge. Three miles farther southwest, in the NE. ¼ sec. 6, T. 17 N., R. 77 W., there are coal outcrops in which the beds dip to the west. The coal here is underlain by sandy shale or shaly sandstone that dips beneath a high north-south ridge which is apparently formed by the same sandstone that forms the ridge on the Bengaugh ranch, where the fossils were found. South of this point the rocks are mostly obscured by Quaternary deposits.

The following is a section from Lookout Flat to old Miser station:

Section of Montana group, Lookout Flat to old Miser station, Wyoming.

	Feet.
Upper part of Montana:	
Soil and terrace gravel of Lookout Flat.	
Shale	142
Brown sandstone bowlders, concretionary, fossiliferous (fossils in upper list on p. 42)	5
Soft gray sand, with sandstone concretions	10
Buff shale	200
Concretionary sandstone, with gasteropods and baculites	5
Gray sandstone	12
Buff shale	150
Massive disintegrated gray sandstone; no fossils	20
Shale	125
Massive buff and brown botryoidal sandstone, baculites	15
Black shale, with beds of coal	558
Shaly sandstone and shale containing Pine Ridge coal	30
Massive white to gray sandstone, some shale in lenses (prominent in Pine Ridge)	60
Lower part of Montana:	
Shale	300±
Brown sandstone, with concretionary bowlders; very few fossils	5
Shale	225
Sandstone nodules	2
Shale	240
Concretionary masses of fossiliferous sandstone (fossils in longest list on p. 42)	15
Shale	300
Brown sandstone, with concretionary masses; few fossils	3
Shale	115
Gray sandstone; plants, baculites (?)	5
Shale	425
Shale and claystone lenses, with baculites	10
Shale	150
Sandstone, concretionary masses	5
Black shale and thin beds of nodular sandstone	2,350
Niobrara formation	200

Fossils and age.—The coal-bearing series in the neighborhood of Rock Creek and Cooper Creek near the old stage road has been known for thirty years or more. The geologists of the Fortieth Parallel Survey recognized its stratigraphic position beneath marine Cretaceous beds and referred it to the Fox Hills. In 1897 these beds and the adjacent formations were examined by T. W. Stanton and F. H. Knowlton, with results which have been published in a paper on the Laramie formation in Wyoming.[a] The following statements are quoted from that paper:

One of the sections in which the relations of the different horizons are best exhibited is near Harpers station, on the Union Pacific Railroad, and within 1 or 2 miles of the original position of Miser station, which is mentioned in some of the earlier geological

[a] Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Bull. Geol. Soc. America, vol. 8, 1897, pp. 137-142.

reports. One mile northwest of Harpers there is an exposure of white sandstone with clays and coal seams, showing a total thickness of about 40 feet and dipping from 9° to 10° S. Fossil plants are abundant near the base of the exposure and are common in a band 20 to 25 feet higher, but the number of species represented is not large. They are interesting, however, from the fact that they are of certainly lower Laramie types or even older. The following is the list:

Sequoia reichenbachi (?) Gein.	Anemia subcretacea (Sap.) Gard. and Ett.
Brachyphyllum n. sp.	Cinnamomum affine Lx.

The beds immediately overlying the coal-bearing series are usually covered, consisting apparently of soft clay shales. A fortunate exposure about 200 yards south of the plant-bearing locality, and consequently little more than 100 feet higher, shows a few feet of such clays with harder bands and concretions that have yielded the following characteristic Cretaceous species:

Chlamys nebrascensis M. and H.	Baculites ovatus Say.
Inoceramus cripsii var. barabini Morton.	

These species occur in both the Fort Pierre and the Fox Hills beds, which are not very clearly differentiated in this region, but the fauna of the underlying beds shows that we are here probably in the Fox Hills beds. Since our return from the field Professor Knight informs us that he has found a Fox Hills fauna fully a mile farther south, and probably 1,000 feet higher than the plant-bearing horizon.

This same coal and plant horizon is exposed on the west side of the railroad, extending westward several miles toward Rock Creek from a point about 1 mile west of Harpers. The light-colored sandstones associated with the coal are here exposed to a thickness of about 75 feet, dipping 17° S. and forming a prominent line of cliffs. In the upper part of the exposure, at a locality about 5 miles west of Harpers, a few fossil plants were collected, including *Sequoia reichenbachii* (?) Gein. and *Cinnamomum affine* Lx.

The stratigraphic relation of the plant bed to the overlying marine strata was again confirmed by finding a fossiliferous horizon in brown and gray sandstone from 500 to 600 feet above the plant zone and apparently conformable with it. The following Montana species were obtained here:

Ostrea sp.	Baculites compressus Say.
Avicula nebrascana E. and S.	Scaphites sp.
Baculites ovatus Say.	

The beds below the coal horizon probably belong to the upper part of the Fort Pierre, but on the Laramie Plains, as in many other regions, no sharp distinction, either paleontologic or lithologic, can be drawn between the Fort Pierre and the Fox Hills, and it is usually more convenient, as well as safer, to speak of them collectively as the Montana formation. These lower beds contain several fossiliferous horizons, two of which are especially prominent, both on account of the number and variety of their fossils and from the fact that they are in hard sandstones, whose outcrops form narrow ridges that can be traced continuously for several miles on both sides of the railroad near Harpers. Collections were made from the upper of these horizons, which is from 400 to 500 feet below the coal, at several localities within the limits just indicated.

The list of species is as follows:

Ostrea inornata M. and H.
Ostrea plumosa Morton.
Syncylonema rigida (H. and M.).
Avicula linguæformis E. and S.
Inoceramus cripsii var. barabini Morton.
Inoceramus sagensis Owen.
Inoceramus sagensis Owen, var.
Inoceramus n. sp.
Modiola meeki (E. and S.).
Pinna lakesi White.
Limopsis parvula M. and H.
Eriphyla gregaria M. and H.
Liopistha (Cymella) undata M. and H.
Dentalium gracile H. and M.
Margarita nebrascensis M. and H.
Lunatia occidentalis M. and H.
Anchura rostrata (Gabb).
Cerithiopsis moreauensis M. and H.
Fasciolaria (Piestochilus) alleni White.
Fusus (Serrifusus) dakotensis M. and H. var.
Baculites ovatus Say.
Placenticeras placenta (Dekay).
Placenticeras placenta var. intercalare M. and H.
Ptychoceras mortoni M. and H. (?).
Ptychoceras crassum Whitfield.
Heteroceras angulatum M. and H. (?).
Heteroceras nebrascense M. and H.
Heteroceras cochleatum M. and H.
Emperoceras beecheri Hyatt (?).
Helicoceras mortoni var. tenuicostatum M. and H.
Scaphites nodosus var. brevis Meek.

The other fossiliferous horizon, which is 300 or 400 feet lower, yields many of the same species, together with a few others that seem to be peculiar to it, as will be seen by the following list:

Ostrea pellucida M. and H.
Ostrea inornata M. and H.
Anomia sp.
Syncyclonema rigida (H. and M.).
Camptonectes cf. parvus Whitfield.
Avicula linguæformis E. and S.
Avicula nebrascana E. and S.
Gervillia sp.
Inoceramus cripsii var. barabini Morton.
Inoceramus sagensis var. nebrascensis Owen.
Inoceramus pertenuis M. and H.
Modiola alternata M. and H.
Pinna lakesi White.
Yoldia evansana M. and H.
Trigonia n. sp.
Caprinella coralloidea H. and M.
Protocardia subquadrata (E. and S.).
Cardium speciosum M. and H.
Legumen planulatum Conrad.
Tellina scitula M. and H.
Glycimeris berthoudi White.
Anatina sp.
Liopistha (Cymella) undata M. and H.
Mactra sp.
Dentalium gracile H. and M.
Lunatia occidentalis M. and H.
Vanikoro ambigua M. and H.
Margarita nebrascensis M. and H.
Anchura americana (E. and S.).
Anchura rostrata (Gabb).
Aporrhais meeki Whitf. (?).
Fusus (Serrifusus) dakotensis M. and H.
Pyrifusus newberryi M. and H. (?).
Fasciolaria (Mesorhytis) gracilenta M. and H. (?).
Anisomyon borealis M. and H.
Anisomyon patelliformis M. and H.
Cylichna sp.
Actæon sp.
Pachydiscus complexus (H. and M.).
Placenticeras placenta var. intercalare M. and H.
Baculites ovatus Say.
Ptychoceras crassum Whitf.
Heteroceras sp.
Helicoceras mortoni var. tenuicostatum M. and H.

The species of these lists are nearly all of common occurrence in the Montana formation of the Rocky Mountain region, but a few of them are worthy of special notice. *Pachydiscus complexus* (H. and M.), which has hitherto been known from a few immature specimens, is here not rare, and attains a diameter of 6 or 8 inches. At least two other species not hitherto reported from the Northwest—*Legumen planulatum* and *Anchura rostrata*—are common in the Ripley beds of Alabama, Mississippi, and Texas, and the undescribed *Trigonia* is closely related to *T. eufalensis*, also from the Ripley.

The *Legumen* is apparently congeneric with Meek's *Barodă wyomingensis*. New collections are thus gradually increasing the number of forms common to the Ripley and Montana formations, although the specific differences between these two presumably contemporaneous faunas are still so numerous that we must assume either considerable climatic differences or partial isolation of the two areas of deposition.

Fossil plants were obtained on the Laramie Plains at three other localities where the stratigraphic position is not so plainly evident as at the localities already mentioned. One of these is near Dunn's ranch on Laramie River, 6 miles east of Harpers, where the following species were collected:

Myrica torreyi Lx.
Quercus acrodon Lx.
Ficus planicostata Lx.
Celastrus n. sp.
Salix sp.
Spathites sp.

It is almost certain that this locality is very near the coal and plant bearing horizon already discussed, yet none of the plants are common to the two localities.

Near the old stage road on the north fork of Dutton Creek, between Rock and Cooper creeks, there is a small coal bed that has been mined to some extent for local use. It is probably the one spoken of as the "Cooper Creek coal" in the reports cited. The shale overlying the coal and the still higher sandstone both contain fossil plants, among which the following, mostly from the shale, were recognized:

Aspidium n. sp.
Asplenium n. sp.
Woodwardia n. sp.
Brachyphyllum n. sp.
Sequoia reichenbachi Gein.
Trapa (?) microphylla Lx.
Ficus sp.
Castalia n. sp.
Asimina eocenica Lx.
Diospyros (?) ficoidea Lx.

The evidence afforded by these plants, while somewhat conflicting, tends to place this horizon quite low down in the series, or approximately similar to the plant horizon at Harpers station. Two of the species (*Brachyphyllum* n. sp. and *Sequoia reichenbachi*) are found at Harpers station and two others of the named species (*Trapa* (?) *microphylla* and *Diospyrus* (?) *ficoidea*) are found at Black Buttes and Point of Rocks. The latter species are also found in the Fort Union beds, but in the lower horizon. The other named species (*Asimina eocenica*), depending on a single example, has been found in the Denver beds at Golden, Colo., and at Carbon, Wyo. The unnamed species, as far as they have affinities, appear to approach more closely to those of the so-called true Laramie.

The associated strata are not exposed in the immediate neighborhood, but about 3 miles to the southwest, near the old stage road crossing Cooper Creek, beds that are certainly higher in position are very fossiliferous, yielding a characteristic Fox Hills fauna, as follows:

Micrabacia americana M. and H.
Ostrea sp.
Anomia sp.
Inoceramus cripsii var. barabini Morton.
Inoceramus sagensis var. nebrascensis Owen.
Avicula linguæformis E. and S.
Avicula nebrascana E. and S.
Gervillia sp.
Modiola galpiniana (E. and S.).
Pectunctulus wyomingensis (Meek).
Protocardia subquadrata (E. and S.).
Syncyclonema rigida (H. and M.).
Lucina subundata H. and M.
Crassatellina sp.
Tancredia americana M. and H
Callista (Dosiniopsis) nebrascensis M. and H.
Tellina scitula M. and H.
Goniomya americana M. and H.
Corbulamella gregaria M. and H.
Martesia sp.
Lunatia concinna (H. and M.).
Capulus sp.
Nautilus dekayi Morton.
Baculites ovatus Say.
Scaphites nodosus (Owen).

The third of the plant localities above referred to is 6 or 7 miles northeast of the coal opening last mentioned. It is at a coal mine now known as the "Dutton Creek" mine, although it is not on Dutton Creek, but in a ravine leading down to Rock Creek, and it may be the Rock Creek coal of the earlier reports. The exposures in the neighborhood are small, and we were unable to determine its stratigraphic relations with any of the other coal beds examined or with any established horizon. The evidence of the fossil plants, which are abundant in the shales and sandstones immediately above the coal, is in favor of correlating the coal with that at Carbon and assigning it to a higher horizon than the other coal beds of the Laramie Plains. The following species were collected:

Anemia.
Glyptostrobus ungeri (?).
Salix media (?).
Populus arctica Heer.
Populus knightii n. sp. Kn.
Quercus platania Heer.
Alnus kefersteinii (Göpp.) Ung.
Corylus macquarrii (Forbes) Heer.
Trapa n. sp.
Betula stevensoni Lx.
Platanus sp.
Ficus uncata Lx.
Ficus 2 sp. nov.
Ficus pseudopopulus Lx.
Juglans rugosa Lx.
Grewiopsis saportanea Lx.
Asimina eocenica Lx.
Sapindus n. sp.
Cissus tricuspidata Lx.
Fraxinus sp.
Magnolia tenuirachis Lx.

Of the fifteen species identified with previously known forms, no less than seven are found at Carbon, often in great abundance, and three of these are known from no other place. Several of the remaining species are reported from Evanston or in higher beds. There can be little doubt as to their affinities with Carbon, and we therefore refer these beds provisionally to this horizon.

It is evident from the preceding notes that the coal-bearing series of the Laramie Plains is in large part, if not wholly, older than the true Laramie, as that formation is usually defined, although it yields what has been supposed to be a Laramie flora—that is, instead of conformably overlying the Fox Hills beds, it is overlain by them or included within them.

Fossils collected from the Montana group at various localities west and northwest of Laramie have been determined by Stanton as follows: In a sandy layer in the upper beds of shale in the west end of The Big Hollow were found *Inoceramus barabini*, *Mactra gracilis*, and *Baculites anceps*. In sandy beds a few hundred feet higher, in sec. 16, T. 15 N., R. 76 W., the fossils collected are *Inoceramus barabini*, *Cardium speciosum*, and *Mytilus* cf. *subarcuatus*, and in still higher beds a short distance north of Table Mountain occur large numbers of *Cardium speciosum*, a form which has wide range of occurrence in the Montana. In the prominent point a mile east of Table Mountain, in the lowest heavy sandstone of the upper part of the Montana as here divided, there was found the impression of a remarkable egg case of a fish of chimæroid character, classed by Gill in the Harriotta, a family which has living forms that are all deep-sea dwellers. This sandstone appears in a prominent bluff on the north bank of Little Laramie River at the ranch of J. Ernest in sec. 3, T. 16 N., R. 76 W., where it yields many fossils, including *Inoceramus* *barabini*, *I. sagensis*, *Avicula linguiformis*, *A. nebrascana*, and *Baculites compressus*. The first and last of these forms also occur in the sandy beds which intervene between the massive sandstone and the top of the thick mass of shales of the lower part of the Montana. These sandy beds yielded *Nucula planimarginata*, *Lucina*, and *Cinulia* on the south shore of James Lake. In the north bank of Little Laramie River, at a point 2½ miles north of Carroll Lake, the shale member yielded *Mactra gracilis*, *Baculites ovatus*, and *B. anceps* var. *obtusus*, forms which are believed to represent a high Pierre horizon. In upper beds of the shale member a mile southeast of James Lake, in the SW. ¼ NW. ¼ sec. 7, T. 17 N., R. 75 W., was found a nearly complete skeleton of a large saurian which has not yet been classified. In upper beds of the Montana at Bengaugh's ranch on Cooper Creek, in the SE. ¼ sec. 21, T. 18 N., R. 77 W., the following were found:

Inoceramus cripsii var. barabini Morton.
Inoceramus sagensis Owen.
Ostrea pellucida M. and H.
Avicula linguiformis E. and S.
Avicula nebrascana E. and S.
Pectunculus wyomingensis (Meek).
Modiola galpiniana (E. and S.).
Tancredia americana M. and H.
Callista (Dosiniopsis) nebrascensis M. and H.
Baculites ovatus Say.
Micrabacia americana M. and H.
Capulus.
Anomia.
Pentacrinus.
Serpula.

The following were collected from the upper portion of the lower part of the Montana, as shown in the section on page 37, in the SE. ¼ sec. 8, T. 20 N., R. 76 W., a short distance from the base of Pine Ridge, 2 miles southeast of Rock River station:

Ostrea pellucida M. and H.
Syncyclonema rigida H. and M.
Avicula nebrascana E. and S.
Avicula linguiformis E. and S.
Inoceramus sagensis Owen.
Pinna lakesi White.
Yoldia evansi M. and H.
Cardium speciosum M. and H.
Legumen planulatum Conrad.
Tellina scitula.
Liopistha (Cymella) undata M. and H.
Corbulamella gregaria M. and H.
Anchura rostrata Gabb.
Anchura americana E. and S.
Fasciolaria (Piestocheilus) alleni White.
Fusus (Serrifusus) dakotensis M. and H.
Baculites ovatus Say.
Helicoceras mortoni var. tenuicostatum M. and H.
Placenticeras intercalare M. and H.
Leptosolen.
Volutomorpha (?).
Actæon.
Heteroceras.

From beds slightly higher were obtained *Inoceramus cripsii* var. *barabini* and *I. vanuxemi*.

From beds 1,100 feet above the sandstone in Pine Ridge and 150 feet below the top of Lookout Flat, as shown in the section on page 37, the following were obtained:

Avicula linguiformis E. and S.
Inoceramus cripsii var. barabini Morton.
Protocardia subquadrata E. and S.
Baculites ovatus Say.
Baculites compressus Say.
Ostrea.
Lucina.

TERTIARY SYSTEM.

There are several deposits of Tertiary age in the region to which this report relates, but, except in the valley of the Little Medicine, their age has not been ascertained.

COOPER LAKE BASIN.

Beginning on the ridge north of Fourmile Creek and extending northward beyond Dutton Creek there is a basin of about 125 square miles, containing a Tertiary deposit probably of Bridger or Wasatch age. The rocks are sandy clays, buff, bright blue, yellow, and terra cotta in color, with irregular concretionary bodies of sandstone and lenses of claystone. They rest upon or are intercalated with beds of sand and conglomerate. The clay members give rise to extensive badland areas, especially along the south side of Cooper Creek. The beds appear to lie nearly level, except along a portion of the south side of the area, where they show very low dips to the northwest. The formation lies unconformably upon the Montana group, but, except along its western margin, there is no great discordance in dip.

Half a mile northeast of the north end of Sprague lane, in the NE. ¼ sec. 35, T. 19 N., R. 75 W., the bluff shows the following section:

Section of Tertiary beds in the NE. ¼ sec. 35, T. 19 N., R. 75 W.

	Feet.
Terrace gravel and soil	2
Buff sand with pinnacles of indurated sandstone, some coarse grained	10
Irregularly deposited coarse dark terra-cotta nodular sandstone	⅛–1
Yellow, purple, and terra-cotta sandy clay	20
Soft conglomerate, thickness unknown, resembling the deposits south of Jelm.	

Similar beds outcrop near the east shore of Cooper Lake, about 2½ miles farther northwest. In the bluff running through the N. ½ sec. 12, T. 18 N., R. 76 W., along the south side of Cooper Creek valley, well-developed badland topography is presented. A small butte in this region has the following section:

Section of Tertiary beds in the N. ½ sec. 12, T. 18 N., R. 76 W.

	Feet.
Blue sandy clay	4
Yellow and terra-cotta, sandy clay	6
Sandy blue clay with irregular white sandstone beds	10

Badlands also appear in the central portion of T. 19 N., R. 76 W. Badlands are not developed on Dutton Creek, but near the Empire ranch house, in the NE. ¼ sec. 22, T. 19 N., R. 77 W., the fine gravelly mortar beds outcrop in banks 10 feet or more in height. The thickness of the Tertiary in this region is probably between 150 and 200 feet. No fossils were found in it.

A well bored in the NE. ¼ NW. ¼ sec. 27, T. 19 N., R. 77 W., on Dutton Creek, passed through Tertiary deposits into the underlying Montana. The Tertiary was reached beneath 43 feet of loose sand and gravel, and is reported to consist of 332 feet of "soapstone," sand, and gravel, ranging from 10 to 25 feet in thickness, the whole resting upon 60 feet of sandstone, which carries two thin veins of coal and belongs to the upper part of the Montana.

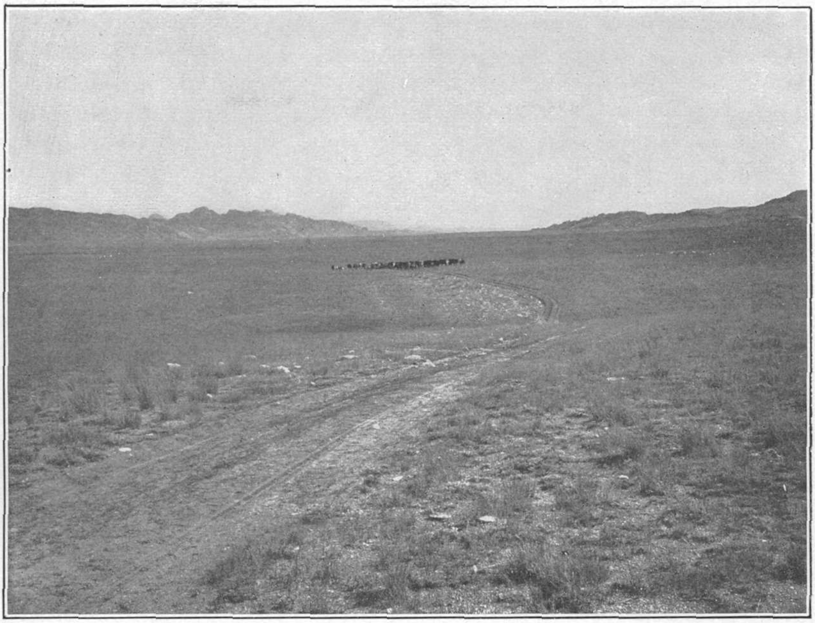
SHEEP MOUNTAIN-RED MOUNTAIN REGION.

On the high slopes at the south end of the Centennial Valley and also south and west of Ring and Red mountains there are deposits of supposed Tertiary age. The altitudes range from 8,000 to 9,000 feet and the underlying formations range from the pre-Cambrian crystalline rocks to the Niobrara, most of the deposits at the south end of the Centennial Valley lying upon the pre-Cambrian. The material is an incoherent mixture of sand and gravel, mostly derived from the crystalline rocks and ranging in size from small pebbles up to large bowlders. In places, especially near the bottom, the material is cemented into a rather firm arkose or conglomerate with a matrix mostly of lime. The topography is very characteristic, consisting of low rounded hills in the midst of rough ridges of granite and sedimentary rocks. The beds lie nearly level but on an uneven surface, and the maximum thickness is apparently between 200 and 250 feet. No evidence was obtained as to the age of the beds and they may be as old as Wasatch or much younger.

LITTLE MEDICINE BOW VALLEY.

A large portion of the valley of Little Medicine Bow Creek and the mountain slopes to the north are occupied by sands and sandy clays of the Chadron formation of the White River group and possibly by some of later Tertiary age. These deposits lie unconformably across various older formations, from granite to the upper beds of the Montana, and west of Little Medicine post-office reach a thickness of several hundred feet. They begin at an altitude of about 7,000 feet and extend up the mountain slopes and up some of the valleys to and across divides at altitudes of more than 7,500 feet. On the northwest side of Little Medicine Bow Valley they rise in a steep badland escarpment facing southeastward which extends far to the west. The summit of this feature is a high plateau which, rising gently to the northeast, extends to the summit of the range on the divide at the head of Boxelder Creek.

One broad deposit caps the divide in the Laramie Plains west of Garrett. It also extends northward up the valley of North Laramie River and through a gap at its head which crosses the main Laramie Mountains to the head of the valley of Labonte Creek. (See Pl. VII, *A*.)



A. VALLEY FILLED WITH TERTIARY DEPOSITS AT HEAD OF NORTH LARAMIE RIVER, SUMMIT OF LARAMIE MOUNTAINS, WYOMING.

B. SPRINGS AT FISH HATCHERY, SOUTH OF LARAMIE, WYO.

Smaller deposits cap the high plateau northeast of Lake Ione and the prominent butte east of McGill, and one extends through the elevated cross valley southeast of Garrett.

The materials in the northern part of the area are mainly sands and sandstones or conglomerates. Along Little Medicine Bow Creek and adjacent slopes there are extensive badlands developed in white, gray, and greenish sands and sandy clays, and small outcrops of these materials appear in the other areas. Numerous remains of *Titanotherium* and *Rhinoceros* of Oligocene age occur in them, affording a basis for definite correlation with the Chadron formation of the White River group. In places near the mountain slopes there are bowlder beds, notably on the high terrace east of Lake Ione, on the McGill butte, and in the southwest corner of T. 26 N., R. 74 W., where there are many bowlders of granite and other rocks from a few inches to 6 feet in diameter. These coarse deposits appear to overlie the finer ones, and in places the latter are underlain by old channels filled with loose coarse sandstone. Possibly some of the upper deposits and those at the higher levels represent Tertiary beds of later age than Chadron, namely, the Brule or upper member of the White River group. Possibly also the Arikaree formation is represented here, for its deposits extend high on the eastern flanks of the Laramie Mountains.

QUATERNARY SYSTEM.

Extensive deposits of Quaternary age are present in the Laramie Basin as alluvium and high-terrace mantles, representing various stages of topographic development of the region. A small amount of glacial drift also occurs.

GLACIAL DRIFT.

A well-developed moraine which appears on North Fork of Little Laramie River a short distance north of Centennial is the product of an old glacier that once descended from the Medicine Bow Mountains. The material consists of till and bowlders of various sizes. The altitude is about 8,400 feet and the topography is typically morainic, with pits some of which are 30 feet deep. The bowlders are of varied composition, but a large proportion are made up of quartzite and quartzitic conglomerate, probably derived from the Algonkian rocks in the upper portion of the Medicine Bow Mountains. The mesa which extends from this moraine to the vicinity of Centennial village is also covered with these bowlders, as are likewise two small hills 2 miles southeast of Centennial.

HIGH TERRACES.

Nearly all the low divide ridges throughout the Laramie Basin are covered by deposits of gravel, sand, and loam, many of them from 30 to 50 feet thick. They are from 20 to 100 feet higher than the alluvial plains along the present valleys and represent the undulating surface of the basin at various stages of topographic development earlier than the present. Possibly some of the higher deposits, such for instance as that occupying a wide area northeast of Medicine Bow, consist of remnants of Tertiary beds. The deposits are thickest and most extensive, however, in the vicinity of Laramie River and were laid down by that stream and its branches at no very remote period of geologic time. Their distribution is not shown on the map because of their intricate and indefinite boundaries.

ALLUVIUM.

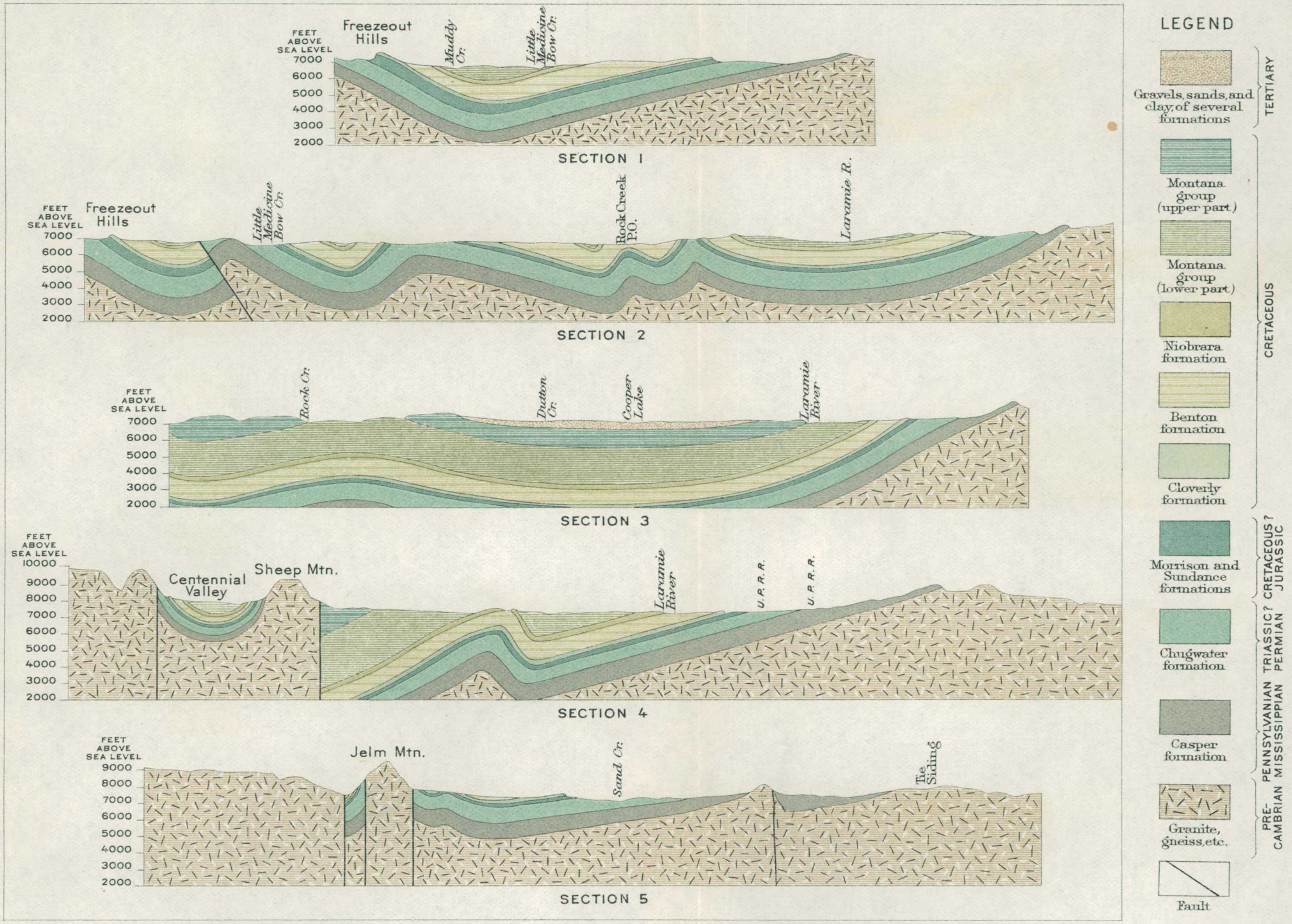
All the larger streams in the Laramie Basin flow through wide valleys filled with alluvial deposits varying in thickness but in many places 50 to 60 feet deep. In general they are widest in the outcrop zones of the softer rocks and they become narrower, thin, and discontinuous in the granite areas, notably along the canyon of Laramie River. The widest areas are along Laramie and Little Laramie rivers, west and southwest of the city of Laramie, but wide alluvial flats also extend up Rock Creek from the railroad to the foot of the mountains, and there are alluvial areas of moderate width along Medicine Bow and Little Medicine Bow creeks and some of their branches.

STRUCTURE.

Structurally the Laramie Basin region is a broad syncline trending north and south with gentle dips on the east side and steep dips or a great fault on the west side. This broad trough is traversed by a number of anticlines which start in various directions from the border of the basin and die out toward its middle. In the region about Medicine Bow these flexures are numerous and cause much complexity in the structure. The five sections in Plate VIII illustrate the principal structural features.

LARAMIE MOUNTAIN SLOPES.

The strata lying along the western slope of the Laramie Mountains and constituting the summits near Laramie have a general westerly dip at moderate angles, averaging 3° near Red Buttes, 4° near Laramie, 6° east of Wyoming, 14° near Sybille Creek, 4° near McGill, 5° near Marshall, and 6° near Little Medicine. The strike is uniformly north and south for many miles near Laramie and north-northwest and south-southeast from North Laramie River northward, except in an area north of Boswell Spring, where an anticline deflects the strata to the west, and for a short distance from Pilot Hill northward, where a small anticline causes a slight offset in the ridge. A short distance south of Sybille Canyon the strata are flexed and broken for a mile or more. On the great monocline on the western



GEOLOGIC SECTIONS ACROSS LARAMIE BASIN

5 0 5 10 miles

1908

slope of Laramie Mountains the strata descend in regular order, and in the center of the basin west of Cooper Lake the base of the sedimentary series is several thousand feet below the surface, as shown in section 3, Plate VIII. At the south end of the basin there is a general upward pitch of the strata; to the north the basin is crossed by a series of extensive corrugations, shown in section 2, Plate VIII.

The monocline of the Laramie Mountain slope is cut by a fault near Tie Siding. This fault, so far as it is marked by the contact of sedimentary rocks with the granite, has a length of about 3 miles, extending north of west from a point near the middle of the north side of sec. 33, T. 13 N., R. 72 W., nearly to the middle of the north side of sec. 25, T. 13 N., R. 73 W. It probably extends some distance beyond the end of the contact of the sedimentary rocks and the granite. The sedimentary rocks dip toward the fault at a low angle. No accurate measurement of the throw is possible, but as the dip of the strata is toward the fault plane the throw can not be less than the difference of elevation between the beds on the ridge and those in the hollow to the north, which is 250 feet. The throw is therefore between 250 and 500 feet. The hade is very steep but the fault plane was not seen, and whether the fault is normal or reverse is not known.

A small fault traverses the Casper formation east and northeast of Pilot Knob, on the axis of the small anticline that crosses the mountain slope east of Howell. On Horse Creek this fault has an upthrow of about 200 feet on the east side.

BOULDER RIDGE ANTICLINE.

In the southern portion of the Laramie Basin the main syncline is divided into two lobes by a prominent anticline extending from the south and finally pitching down to the north. One of its most marked features is Boulder Ridge, a rugged prominence of granite which extends for some distance northward along the axis of the uplift. The flexure is conspicuous in the formations from Chugwater to Benton south of Hutton Lake and in the Niobrara formation in the west end of The Big Hollow, and its effects are clearly marked by uplift in the Montana beds for some distance farther north. In general this anticline presents very steep dips on the east side and gentle dips on the west. From the north end of Boulder Ridge to the south line of T. 13 N. the east side of the anticline is faulted. This is indicated by the facts that the contact line between the granite and the Casper formation is nearly straight, and that as the various limestone and sandstone beds swing in to the west they are abruptly cut off by the granite, which here rises in a steep front 300 to 500 feet high. South of the township line the eastern slope of Boulder Ridge is less abrupt and the sedimentary rocks, which dip to the east at steep angles, extend for some distance up the flank of the ridge. The synclinal area of the Casper formation east of Boulder Ridge terminates in Colorado a short distance south of the state line. On the west side of Boulder Ridge there are gentle slopes of granite which dip beneath the Casper formation at low angles into the wide syncline extending to Red Mountain.

In the northeast corner of T. 13 N., R. 74 W., and in the northwest corner of T. 13 N., R. 73 W., just southeast of Sportsman Lake, there is a small anticline, parallel to the main flexure of Boulder Ridge, which is marked by curved outcrops of the Forelle limestone. On the south side of Hutton Lake the two limbs of the Boulder Ridge anticline are shown, the beds on the west side dipping south of west at an angle of 15° and those on the north side dipping north of east at angles of 50° to 85°. The steeply dipping beds from Morrison to Benton outcrop in a prominent ridge along the south side of the lake. On the east limb of this anticline there is a small ∽-shaped flexure in the Mowry shales which is clearly exposed on the south shore of the lake. On Laramie River the Niobrara dips to the northeast at an angle of 5° on the east side of the Boulder Ridge anticline and at about the same angle to the southwest on its opposite side. Benton outcrops along the axis of the Boulder Ridge anticline as far north as the west end of The Big Hollow. In this hollow the uplift is clearly shown in extensive exposures of the Niobrara, which on the east side of the flexure has nearly vertical dips. (See sec. 4, Pl. VIII.)

RED MOUNTAIN–JELM MOUNTAIN AREA.

Jelm and Ring mountains are due to an anticline of irregular form crumpling and faulting the beds along the southwestern margin of the syncline of Laramie Basin. There are several axes with numerous variations in pitch but having a general north-south strike. To the south, in Red Mountain and in Colorado, they merge into a broad area of gentle undulations well exhibited in beds from Casper to Cloverly. In the depression east of Red Mountain the strata are broken by a fault with downthrow on the east side amounting to several hundred feet. It extends from the south, in Colorado, and ends a few miles northeast of Red Mountain in an eastward-dipping monocline of Chugwater (upper part) and overlying formations. North of Red Mountain there is a prominent rise in the anticlines on the west bringing up the pre-Cambrian in Ring Mountain and again in Jelm Mountain. The anticline on the east shows granite in a short ridge just east of Ring Mountain, but the axis then bears to the northeast and the anticline pitches downward rapidly. It appears to be continued through the center of T. 14 N., R. 76 W., in the Benton, Niobrara, and Pierre beds, which are mostly covered by Quaternary deposits. The strata also pitch steeply to the north at the north end of Jelm Mountain until they reach the fault which cuts across the south end of Sheep Mountain.

West of the anticline of Jelm Mountain there is a narrow syncline holding beds from Casper to Niobrara dropped by a pair of faults, as shown in section 5, Plate VIII. Jelm post-office is on alluvium on Benton shales, with a continuous succession of formations to Chugwater exposed at intervals on the adjacent slopes. The faulting is plainly shown on the west side within a mile north and south of the post-office, where all the formations are cut off diagonally by the schists. Two miles farther north the Niobrara occurs, dipping gently eastward and faulted against schists on the west side of the valley. From a point a mile south of Jelm northward to Woods Landing the syncline has been squeezed and faulted in various ways and the structure is very complicated. The details are largely concealed by the steep slopes of detritus from the hills. To the south the valley widens out and the structure becomes more simple. About Jelm the syncline is well marked by the outcropping upturned edges of the Morrison and Cloverly formations. It is closely compressed with vertical dips on the west side and 45° dips on the east side, and the width from one outcrop of the Cloverly to the other is less than one-half mile. A mile east of Jelm there is another syncline of Cloverly very closely compressed with vertical dips on either limb. The axis bears north and northwest and is apparently marked by a narrow outcrop of Benton. Just east of this syncline the Chugwater formation is faulted against vertical sandstone beds of the Cloverly. The Morrison does not appear, probably being faulted out of sight. Relations indicating two faults are exhibited half a mile south of Woods Landing, where on the east side of the valley the Chugwater red beds are in contact with the schists, toward which they dip at an angle of 45°. Lower down the slope the Niobrara is exposed, dipping in the same direction.

CENTENNIAL VALLEY.

The Centennial Valley consists of a symmetrical syncline with dips of 40° to 50° W. along the flank of Sheep Mountain and of 35° to 80° E. at the foot of the Medicine Bow Mountains. The succession of rocks is complete from Casper to Montana along the east side of the valley, but on the west side faulting at a point 3 miles south of Centennial cuts out the Casper formation entirely. The syncline is cut off by faults at both ends of the valley. At the southeast end the older formations pass beneath the Tertiary so that their contact with the crystalline rocks is not seen, but along the southwest edge of the valley the fault is plainly indicated, the granite coming down to the floor of the valley along a diagonal line so that finally it is in contact with the

Montana. Northwest of Centennial the sedimentary rocks disappear beneath the glacial débris of North Fork, but the granite crosses the strike of beds from Casper to Montana on a fault which joins the Sheep Mountain fault.

SHEEP MOUNTAIN TO ARLINGTON.

The contact of the sedimentary rocks and the granites northward from a point 2 miles north of Woods Landing is very irregular owing to a cross fault associated with irregular flexing. At this point the Chugwater beds dip toward the schists at an angle of 12° near the contact. The south end of Sheep Mountain is marked by an escarpment which corresponds to the junction of the schists with the granite that constitutes most of Sheep Mountain. The granite at the east face of this mountain rises about 250 to 300 feet higher than the schists immediately south, and farther west the granite is 800 feet higher than the Tertiary deposits which lie upon the old level eroded surface of the schists. The top of Sheep Mountain shows another such level eroded surface, apparently once continuous with the surface just mentioned, and now uplifted by the dislocation. The schist mass appears to have been rotated on an axis lying near the east face of the mountain, for along the apparent continuation of the fault on the plains to the east the Morrison is in contact with the Niobrara, indicating downthrow on the north side, whereas west of the axis of rotation the downthrow is to the south. To the west this fault probably cuts off the beds in the south end of the Centennial Valley and passes into the Medicine Bow Mountains. In the valley the upthrow is on the south side.

For a mile along the east base of Sheep Mountain north of this cross fault a long slope of débris entirely obscures the contact, but farther north there are a few outcrops of Chugwater and Niobrara, the former beds lying higher in the slope than the latter and both dipping toward the mountain at an angle of 70°. A great fault begins in this vicinity and extends northward beyond Arlington. West of Lake Hattie this fault brings the upper beds of the Montana, dipping gently to the west, into contact with the granite, as shown in section 4, Plate VIII. The granite rises in a steep slope to the crest of Sheep Mountain, 1,500 feet above. The amount of throw diminishes toward the north as the Sheep Mountain anticline pitches down, and is small in crossing the syncline of the Centennial Valley east of Centennial. Farther north the fault reaches the flank of the uplift of the Medicine Bow Mountains, and granites and the Montana are again in contact. This relation extends beyond Rock Creek except in a ridge south of Arlington, where some red beds (presumably Chugwater, probably lying on Casper formation) appear for a short distance along the west side of the fault. From Mill Creek nearly to Rock Creek a syncline holding upper beds of the Montana extends parallel to this fault. The dips are 30° on both limbs. Next east is an anticline in Montana shales forming the west margin of the deep portion of the Montana basin which lies about the Cooper Lake region. Dips on the east side of this anticline range from 20° to 40° and on the west side from 5° to 30°. The relations near the mountains in this belt are greatly obscured by glacial drift and talus, but local exposures mostly present moderately steep dips. The Montana beds dip from 20° to 40° E. along the west side of the Tertiary area in the Cooper Creek basin.

ROCK RIVER ANTICLINE.

The Rock River anticline begins in the red beds west of McGill. A short distance west of Chalk Bluffs it has the relations shown in section 2, Plate VIII, with steep dips (35° to 50°) on the northwest side and gentle dips on the southeast side. It causes the westward deflection of outcrops ranging in age from Chugwater to Montana, in which the Niobrara formation rises into the prominent exposure in Chalk Bluffs. The lower formations pitch down steeply 6 miles west of these bluffs, but the anticline continues far to the southwest past Rock River station, up the valley of Rock Creek. Along its axis the lower beds of the Montana extend up the wide valley of Rock Creek to the fault at Arlington. The relations in this valley are shown in section 3, Plate VIII. In the vicinity of Chalk Bluffs the beds on the northwest limb dip 20° and those on the other side incline to the southeast at angles of 10° to 14°. At the point where the rim of upper sandstone of the Benton passes beneath the surface 4 miles southeast of Rock Creek post-office the dip is to the west at an angle of 35°. Sandstone and coal in the bank of Rock Creek 5 miles above Rock River station dip to the southeast at angles of 5° to 8°, but the sandstone in the bluff 2 miles farther north dips to the northwest, indicating that the axis of the anticline passes between these points. The Montana sandstones outcrop on both sides of the valley, dipping to the northwest on the northwest side and to the southeast on the southeast side. The dips are mostly low. On the south side of the valley near Rockdale the anticline appears to branch and the southern arm joins the flexure extending along the west side of Cooper Creek basin. Exposures in the valley are poor, owing to the heavy covering of alluvium.

ROCK CREEK ANTICLINE.

A short but prominent anticline passes just north of Rock Creek post-office. It develops in red beds near Boswell Spring, is exhibited in beds ranging from Morrison to Benton near Rock Creek, and disappears in the lower beds of the Montana north of Rock River station.

Its course is from northeast to southwest. At a point along the main road 3 miles northeast of Rock River station a local increase in uplift causes the appearance of a small outcrop of Niobrara. On the west side of the Rock Creek anticline there is a narrow syncline in which the lower shales of the Montana extend for some distance into T. 22 N., R. 75 W., and the ridge of Casper formation is deflected eastward in T. 23 N., R. 74 W. The dips on the southeast side of the uplift are 10°; on the northwest side they range from 70° to vertical. The axis of this anticline passes a short distance south of Boswell Spring, where the dip is 20° N., 72° W., and it is a moderately prominent feature in the ridges of Casper limestone on the mountain slopes east of the spring.

COMO ANTICLINE.

The Como anticline extends from the Laramie Mountains far across the Laramie basin on a nearly west-southwest course. It causes an extensive deflection in schists and limestones in the front ridge southwest of Garrett, and deflects the Chugwater red-bed outcrop far to the west beyond the margin of Carbon County. The prominent Como Ridge, on the southern slope of the uplift, is due to the Cloverly rising on a gentle dip—8° to 10°. It presents a precipitous face to the north, at the top of long slopes of the Morrison, Sundance, and Chugwater formations. This low dip is general on the south side of the uplift, but on the north side the dips approach the vertical. The flexure pitches down steeply at the southwest end of Como Ridge, where the structural relations are clearly shown by the curving outcrops of the upper sandstone of the Benton (Carlile) along the Union Pacific Railroad. Four miles southeast of Medicine Bow the flexure rises again abruptly for a short distance in a low ridge, in which beds from Niobrara to Morrison are exposed. On the north side of the Como anticline there is a syncline which carries the lower shale of the Montana in the region northeast of Medicine Bow and a wide area of Benton shales farther northeast. It finally passes into an angle in the mountain front west of Garrett, where beds from Benton to Casper are covered by Tertiary deposits.

FLATTOP ANTICLINE.

North of Medicine Bow there is a prominent uplift, on the crest of which there is a summit known as Flattop. From Medicine Bow northward to this point the beds rise in regular succession—first the Niobrara, which appears in the river bank at the north end of the iron bridge; then the prominent upper sandstone of the Benton, which causes a sharp outlying ridge (see Pl. VI, *B*); then slopes of Mowry shale on a second ridge in which appear formations from the Benton to the Chugwater. The latter extends down to Little Medicine Bow Creek and partly up the north slope. Higher on this slope the center of the uplift presents the top sandstone of the Casper formation. On the north side of this ridge are exposed red beds dipping to the north and cut off by a fault, along which Niobrara beds appear near the road and the upper sandstone of the Benton farther west. These beds descend into a syncline holding the Montana group which extends to the Freezeout uplift on the northwest and far up the valley of Muddy Creek on the north and northeast. The fault dies out within a short distance to the east and a symmetrical anticline extends up the divide between Bone and Sheep creeks. The dips are all gentle. This anticline exposes Chugwater red beds as far east as the east line of R. 77 W., beyond which there is a downward pitch and the outcrops curve over the flexure. In crossing the axis of the flexure the Cloverly formation rises into a prominent butte in the west side of T. 24 N., R. 76 W. Farther east the flexure is lost in Benton shales mostly covered by Tertiary beds.

FREEZEOUT UPLIFT.

Only the east end of the Freezeout Hills extends into the area shown on the map (Pl. I). It presents the structural relations shown in the left-hand ends of sections 1 and 2, Plate VIII. The structure is that of a half dome, with sides dipping to the east, north, and south. The Chugwater red beds are prominent to the west and are bordered by semicircular outcrops of a succession of formations from Sundance to lower Montana. The Cloverly formation rises in a prominent ridge of which the outer slopes descend to the outcrops of the Benton. A mile or more distant is the Niobrara, partly covered by old terrace deposits, and then the shales of the Montana, which extend up the valley of Muddy Creek and constitute the low ridge between that stream and Little Medicine Bow Creek. Farther north, in T. 26 N., R. 78 W., the pitch to northwest so deepens the basin that it holds the sandstone of the Montana.

MINERAL RESOURCES.

COAL.

Associated with the sandstones of the upper part of the Montana are coal beds ranging in thickness from a few inches to 6 feet or more and occurring at several horizons. The beds appear not to be continuous for long distances and vary greatly in thickness. They are exposed at few points; consequently their extent and relations can not be determined.

One of the first mines in Wyoming was opened by the stage company in 1865, near the old overland trail crossing of Rock Creek. The coal was used for blacksmithing.

On Rock Creek the Diamond Cattle Company has an opening in sec. 7, T. 19 N., R. 78 W., in 6 feet of coal. The product in 1904 was 200 tons, which sold at $2 a ton.

Overlying the massive sandstone of Pine Ridge is a bed of coal which has been opened in a number of localities and at one place mined somewhat extensively. The easternmost opening on this bed is in the SE. ¼ sec. 7, T. 20 N., R. 75 W., on the continuation of Pine Ridge and just east of the old location of the Union Pacific Railroad, 2 miles northeast of Harper. The coal bed is reported to have a thickness of 5 feet. Nothing could be learned as to the amount mined or the quality of the coal.

Another bed of coal has been prospected a mile northwest of Harper station at a horizon south of and several hundred feet above the Pine Ridge coal, but apparently the results were not satisfactory, for no mining was done.

Coal outcrops at intervals along Pine Ridge west of Harper and at one time it was worked to a small extent in the SE. ¼ sec. 16, T. 20 N., R. 76 W. Here the coal had about the same thickness and quality as in other openings on this bed. The dip in all the outcrops in this area is to the south at angles of 10° to 15°.

Coal is exposed near the middle of the north side of sec. 21, T. 20 N., R. 77 W., dipping south at angles of 5° to 8°. It is more than 7 feet thick and appears to be a bright, clean coal. Apparently it is at a horizon several hundred feet below the coal bed in Pine Ridge.

Coal is reported 1 mile farther north, in the bluff on the north side of Rock Creek, where it is associated with a heavy white sandstone which forms a short ridge similar to the main Pine Ridge. The beds here dip to the north, as they are on the north side of the Rock River anticline. This coal is believed to be at the same horizon as that in Pine Ridge.

The following section is reported in a well on the Empire ranch, on Dutton Creek, in the NE. ¼ SW. ¼ sec. 27, T. 19 N., R. 77 W., put down for Judson Sutphin & Co. in 1889:

Record of well at Empire ranch.

	Feet.
Loose sand and gravel	43
Soapstone, sand, and gravel in layers 10 to 25 feet thick (Tertiary)	332
Sandstone, with two small beds of coal	60
Soapstone	45
Sandstone	40
Coal	8
Sandstone	12
Slate	4
Coal	8
Slate	2½
Coal	7½

Doubtless the coal beds reported in this well are those mined 2½ miles to the northwest. The coal borings were analyzed by M. Delafontaine in 1890, with the following results:

Analysis of coal borings from well at Empire ranch.

Specific gravity, 1.51.	
Water (at 212° F.)	4.84
Volatile matter; bright, long flame	37.10
Fixed carbon	50.54
Ash, light fawn color	7.52
	100.00

The coal is noncoking. The large amount of ash appears to be due to some slate fragments intermixed.

In the NE. ¼ sec. 18, T. 19 N., R. 77 W., is the abandoned Terry Fee mine, the "Dutton or Cooper Creek mine" of the early reports. The coal worked here is said to have ranged from 6 to 7 feet in thickness and was a good bright coal, burning with much white ash but no cinders. The roof consists of white sandstone, with a few inches of slate just over the coal. The dip as measured from present exposures is 8° E. The workings extend into the hill for 400 to 500 feet, but the mine has long been abandoned. It is claimed that beneath this coal bed and separated from it by 8 feet of shale there is another bed 7 feet thick. This is in accordance with the succession given in the log of the Empire ranch well, located 2½ miles farther southeast.

Several outcrops of coal are reported 2 miles northeast of the Terry Fee mine, in sec. 4, T. 19 N., R. 77 W., in the valley of Coalbank Creek. The Monarch mine, which is worked from time to time, is situated in the SW. ¼ sec. 8, T. 19 N., R. 77 W. The bed was found to be 5 feet thick and dips south of east at an angle of about 4°. The coal appears to be of good quality. The roof is of shale and stands well. The entry was driven about 200 feet into the hill and several rooms were turned off from it. The chief market for the product of this mine and that of the Terry Fee mine was on local ranches and in the town of Laramie. A production of 500 tons, selling at $2 a ton, was reported in 1904.[a]

Coal outcrops near the center of sec. 20, T. 19 N., R. 77 W. The deposit is 2 to 3 feet thick and consists of several 8 to 10 inch beds of coal separated by bone. The dip is 15° SE. This bed appears to be at a somewhat higher horizon than the coal of Pine Ridge and possibly may be correlated with the unsuccessful prospect a mile northwest of Harper station.

An anticline trends due south from the mines above mentioned, forming sharp north-south ridges in the vicinity of Cooper Creek Cove. In the southeast corner of sec. 17, T. 18 N., R. 77 W., on the east side

[a] Trumbull, L W., Coal resources of Wyoming: Bull. Univ. Wyoming No. 7, 1905.

of this anticline, a heavy white sandstone, probably the same as that which constitutes Pine Ridge, outcrops, dipping to the east at an angle of 40°. No coal, however, has been reported in the vicinity of this sandstone.

Three miles farther southwest, on the west side of this anticline, in the NE. ¼ sec. 6, T. 17 N., R. 77 W., coal outcrops along the road. It dips westward beneath the ridge and may be either one of the coals that lie above the sandstone of Pine Ridge. It is reported that coal croppings continue on this line to Centennial Valley, but none of them were definitely located.

In digging a deep well on Mill Brook, coal was encountered at 300 feet in two beds, one 6 feet and another 3 feet thick.

The following are analyses of coal from the Laramie Basin:

Analyses of coal from the Laramie Basin.[a]

		Water.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Total.
1	Brown mine, Dutton Creek	11.25	36.85	45.00	6.90	1.13	81.85
2	.....do	11.85	34.65	47.30	6.20	1.25	81.95
3	Chase mine, Mill Creek	14.50	34.50	44.75	6.25	1.03	75.25
4	Rock Creek mine	14.40	34.90	39.70	11.00	....	74.60
5	.....do	11.50	32.40	49.70	6.40	....	82.10

[a] Bull. Univ. Wyoming No. 7, 1905. Analyses 1 to 4 by School of Mines, University of Wyoming; 5 by American Smelting and Refining Co.

GYPSUM.

Two varieties of gypsum occur in the Laramie Basin—earthy gypsum, or gypsite, and rock gypsum. The rock gypsum is used together with a very small amount of gypsite in the mill of the Consolidated Plaster Company at Red Buttes; the gypsite is used by the Acme Cement Plaster Company near Laramie.

ROCK GYPSUM.

The thickest deposits of gypsum rock in the Laramie Basin lie along the foot of the north slope of Red Mountain in T. 12 N., R. 76 W., a short distance north of the Wyoming-Colorado line. The gypsum outcrop first appears from beneath the Tertiary deposits near the middle of the west side of sec. 7, winds in and out around the foothills of Red Mountain through secs. 8, 9, and 10, passes out through the northeast corner of sec. 10, bends to the north, swings sharply westward through the middle of sec. 3, and turns northward again near the middle of sec. 4, where the gypsum becomes too thin to be of importance. The base of the gypsum beds throughout this region is marked by a bed of limestone a foot or more thick, crowded with fossils of upper Carboniferous age. A section of the gypsum measured at its maximum development in this vicinity, from the top of the beds on the northern foot of Red Mountain, in sec. 9, down to the fossil bed, is as follows:

Section of gypsum-bearing beds at the base of Red Mountain on the north side.

	Feet.
Red gypsum rock, nearly pure	6
Red shale	35
Gypsum	3
Red shale	10
Gypsum	4
Reddish shale	55
Banded gypsiferous rock	5
Red sandy shale	88
Gypsum, massive	67
Fossiliferous limestone	1
	274

The main gypsum bed, ranging in thickness from 30 to 60 feet, extends nearly the whole length of the outcrop outlined above. The distance to Red Buttes, the nearest point on the railway, is about 25 miles.

Gypsum outcrops near the middle of the north side of sec. 7, T. 13 N., R. 73 W., a mile east of Sportsman Lake, where a small pit shows 4 or 5 feet of pure rock gypsum. Whether this is the full thickness of the bed is not known. A curly, laminated gypsiferous limestone (Forelle) outcrops a quarter of a mile farther east and dips beneath the gypsum. This limestone extends east of north in a low ridge to Forelle and beyond, passing a quarter of a mile east of Red Buttes station.

A mile south of Red Buttes station and a quarter of a mile east of the limestone ridge just described is the deposit of gypsum which has been worked since 1890 by the Consolidated Plaster Company. The beds dip beneath the limestone and are therefore lower than the gypsum at Sportsman Lake. The quarry at present worked is just east of the mill and shows a face of 15 feet of solid gypsum rock, which will probably be increased to 20 feet with further progress into the hill. A quarry formerly worked lies northwest of the mill and shows a face of 8 or 10 feet. The dip of this bed would carry it 25 or 30 feet above the quarry now worked, showing the existence of two beds at this point. The upper bed was struck again near the point where the siding to the mill leaves the main line of the Union Pacific Railroad, but north and south of these points the gypsum appears to thin out and disappear. An analysis of the gypsum from this bed, by D. O'Brine, of the Colorado Agricultural College, is as follows:

Analysis of gypsum from Red Buttes.

CaO	32.5
Al_2O_3	.3
Fe_2O_3	Trace.
SiO_2	.2
SO_3	46.3
H_2O	20.8
	100.1

In the SW. ¼ sec. 2, T. 16 N., R. 73 W., 5 miles northeast of Laramie, gypsum crops out at the northern foot of a small hill. Several test pits show a thickness of 9 or 10 feet of gypsum of excellent quality.

GYPSITE.

Several valuable deposits of gypsum earth, or gypsite, resulting from the disintegration and redeposition of the rock gypsum, are present in the Laramie Basin. The material usually contains about 80 per cent of gypsum, but the percentage varies.

An extensive body of gypsite is worked by the Acme Cement Plaster Company just south of Laramie. The deposit covers almost the whole of sec. 4 and has a depth of 9 feet where worked. The upper 7 feet is pure gypsite, beneath which is a 5-inch red layer underlain by a foot or more of white gypsite resting upon gravel and red clay. The gypsite is in a finely divided state and goes directly to the calcining kettles without grinding or screening. It contains about 20 per cent of impurities, such as sand, clay, and limestone, but these do not interfere with its use for cement plaster. No plaster of Paris is made at this mill.

Another large deposit owned by the Acme Cement Plaster Company occupies almost all of sec. 4, T. 16 N., R. 73 W., lying east of the county road and overlapping the southern part of sec. 3.

Other smaller deposits in the vicinity of Laramie comprise one south of Spring Creek, southeast of the fair grounds; another in the SE. ¼ sec. 28, T. 16 N., R. 73 W., a mile northeast of Laramie; and a third along Soldier Creek extending 1 mile below and 2 miles above the site of old Fort Saunders. A small deposit occurs in the valley of Harney Creek in the NE. ¼ sec. 21, T. 14 N., R. 73 W., a mile southeast of Red Buttes; and another is worked by the Consolidated Plaster Company at Red Buttes. The latter lies just west of the mill and has a depth of 5 or 6 feet. In the manufacture of plaster of Paris the rock gypsum is sorted, the rejected rock being mixed with the gypsite for the manufacture of cement plaster.

An extensive bed of gypsite occupies the lower 2 miles of the valley of Willow Creek to its junction with Lone Tree Creek and extends 2 miles down Fivemile Creek. Another gypsite deposit occupies portions of secs. 33 and 34, T. 14 N., R. 74 W.

Many of the gypsite beds above described have been carefully bored and tested by parties interested in their location, and others have been located by their effect on the vegetation growing over them.

BENTONITE.

OCCURRENCE AND CHARACTER.

The variety of clay known as bentonite occurs in many localities in Wyoming, usually appearing as a bed in the lower portion of the Benton formation. In the Laramie Basin it occurs near the member known as the Mowry shale, as a rule above it and overlain by 20 feet of very dark shales containing concretions. At some localities it is 5 feet or more thick, but generally is much thinner, in places measuring only a few inches.

When freshly exposed, bentonite varies in color from light yellow to light olive-green, with waxy luster, but most of it becomes of a dull cream color on exposure. When freshly uncovered, it appears as a bedded joint clay and breaks out with conchoidal fracture in blocks varying from roughly rectangular shapes to long, slender prisms. The joints are more or less open and here and there contain crystals and plates of gypsum and sulphate of soda. The texture is very fine grained, no grit being perceptible to the touch and very little when the clay is ground between the teeth. Under the microscope it is seen to consist of extremely minute more or less rounded particles of fairly uniform size and apparently of the same mineral nature, with scattered particles of undecomposed labradorite. The clay has a soft unctuous or soapy feel, but is brittle and easily quarried. Owing to its highly absorbent character it clings strongly to the tongue. In weathering it absorbs a large amount of water and increases greatly in volume, forming a frothy mantle on the surface which often resembles hoarfrost. When this dries it becomes a soft white powder. Mixed with the proper amount of water it is exceedingly plastic and with the addition of more water becomes a paste resembling glue. Tests show that it completely absorbs over three times its weight or seven times its volume of water and twice as much glycerine as diatomaceous earth will absorb.

COMPOSITION.

As will be seen from the subjoined table of analyses, bentonite falls under the kaolin group of hydrous silicates of alumina. Its resemblance to ehrenbergite has been pointed out by Knight, and Read considers it a variety of montmorillonite.

Analyses of bentonite from the Laramie Basin, Wyoming.

	Taylor.[a]	Taylor.[b]	Linscott.[c]	Cosgriff.[c]		Cassa Mining Co.[d]	
SiO_2	59.78	58.25	66.5	64.0	64.0	60.18	60.18
Al_2O_3	15.10	24.70	23.9	22.9	24.0	26.11	26.58
Fe_2O_3	2.40	2.61	3.1	3.1	3.2		
MgO	4.14	1.30	1.0	2.0	1.5	2.54	1.01
CaO	.73	1.61	.5	1.0	.6		.23
Na_2O	....	....	....	....	....	.80	1.23
K_2O							....
H_2O	16.26	11.00	5.0	7.0	6.7	10.26	10.26
	98.51	94.47	100.0	100.0	100.0	99.63	99.49

[a] Analyst unknown.
[b] Analysis by H. L. Hodges.
[c] Analyses by John Ogden.
[d] Analyses by Thomas T. Read.

USE.

Shipments of bentonite from the Laramie Basin began in 1888, when several carloads were used by eastern firms in the manufacture of ''hoof packing,'' a dressing or poultice for the inflamed hoofs of horses. Its chief use, however, is to give body and weight in the manufacture of paper, and practically the whole output of the clay for the last few years has been taken by a paper mill in Denver, Colo. Other uses are in antiphlogistine, a proprietary remedial dressing, and as an adulterant in candies and drugs. Though highly plastic it is unsuitable for the manufacture of fire-clay products on account of its ready fusibility. It is a good retarder for use with the hard cement plasters. Its high absorption of glycerine as compared to diatomaceous earth suggests its substitution for that material in the manufacture of dynamite.

DESCRIPTIONS OF LOCALITIES.

Rock Creek region.—The bentonite mines in the Rock Creek region lie at intervals along the outcrop of the Benton formation for a distance of 20 miles. The bed is persistent throughout that distance, although in places it is covered by talus or wash. The principal production of bentonite in the Laramie Basin has been from the Taylor mine, in the NW. ¼ SE. ¼ sec. 30, T. 22 N., R. 75 W., about a quarter of a mile north of old Rock Creek station, now Rock Creek post-office. This mine was opened in 1888. The bentonite outcrops on the slopes of the hill with a thickness of 4 to 5 feet, and dips to the south at an angle of 4° or 5°, the same angle as the slope of the hill, so that the bed is exposed over several acres. The top, consisting of a few inches of weathered débris, is stripped off and the bentonite loaded onto wagons and hauled to Wilcox, the nearest railway station, a distance of 6 miles. It is shipped loose in box cars, either in lumps as it naturally comes from the pit or as the fine loose powder which results from weathering.

In 1897 a pit was opened about 3 miles southeast of the Taylor mine at Linscott's claim, in the NW. ¼ sec. 17, T. 21 N., R. 75 W., near the old line of the Union Pacific Railroad. About 20 carloads were shipped from this place, exhausting the readily accessible supply. Another pit was then opened in the SE. ¼ NE. ¼ sec. 14, T. 22 N., R. 76 W., on the north side of Rock Creek, from which about 100 carloads have been shipped. The thickness and relations are analogous to those at the Taylor mine.

A claim owned by the Cassa Mining Company is located in the N. ½ sec. 10, T. 22 N., R. 76 W., but only samples have been shipped. The claim is a mile in length, and the clay presents the same features as at the other localities.

Another bentonite claim is on the Sam White property, in the NW. ¼ sec. 20, T. 22 N., R. 77 W., on the south slope of Como Ridge. The conditions here are similar to those at the other localities, except that the dip of the beds is steeper and a smaller area is uncovered. Only development work has been done.

Chalk Bluffs.—A bentonite claim is located in the NW. ¼ sec. 12, T. 21 N., R. 75 W., near the prominent point locally known as Chalk Bluffs. The thickness, geologic relations, and quality of the bentonite at this outcrop are the same as in the occurrences already described. No shipments have been made.

Hutton Lakes.—Along the bluff on the northwest shore of North Hutton Lake (Creighton Lake) a bed of bentonite appears as a white band in the black shale of the Benton formation for a distance of 200 yards. This bed is from 3 to 4 feet thick, dips south of west at an angle of about 5°, and lies a short distance above the Mowry shale, which outcrops to the east. Apparently the quality of the bentonite is good.

Sand Creek.—Near the middle of the north side of sec 2, T. 13 N., R. 75 W., in the east bank of Sand Creek, a 4-foot bed of characteristic bentonite is exposed, lying upon 20 feet of soft black shale and overlain by fossiliferous sandstone and light and dark shales. The relation of the bentonite to the Mowry shale is not clear, but probably it lies beneath them.

Riverside.—On the Riverside ranch, in the NE. ¼ sec. 14, T. 13 N., R. 76 W., a bed of much-weathered bentonite less than 2 feet thick lies a few feet above the Mowry beds. The bed is reported to thicken to 4 feet in the SE. ¼ sec. 6, T. 14 N., R. 75 W.

PRODUCTION AND PRICES.

From 1888 to 1895, inclusive, the production of bentonite in this region averaged about 60 tons annually. From that time it gradually increased and it is reported to have been 1,200 tons in 1902. With the closing down of the western paper mills the production almost stopped, and in 1905 only a very small amount was shipped.

In the early period, from 1888 to 1895, the price averaged $25 per ton f. o. b. The price then dropped to $5 per ton, but later it rose to $6 and $7 per ton. The total production to date is approximately 6,000 tons, with a value of $45,000.

SULPHATE OF SODA.

In Albany County there are several deposits of the sulphate of soda in the bottoms of small lake basins. Such deposits occur in the Downey Lakes, 20 miles southwest of Laramie; the Union Pacific Soda Lakes, 13 miles southwest of Laramie; and the Rock Creek

Lakes, 12 miles northwest of Rock Creek post-office. They are all in depressions in the Cretaceous shales or the overlying alluvial deposits, and are the result of the evaporation either of surface drainage or of local springs, or perhaps of both.

The Downey Lakes are three in number and occupy shallow depressions extending in a northeast-southwest direction a short distance west of Alkali Creek. They average a quarter of a mile long and 150 yards wide and have a total area of about 100 acres. The middle lake is somewhat larger than the others and is covered with a crust of nearly solid soda upon which a light corduroy bridge is laid. The deposit consists of alternations of clean sulphate of soda, mud, and mixtures of soda and mud, extending to a depth of 6 to 11 feet. The upper crust is nearly pure white and several inches thick. The northern lake is the lowest and smallest, but its salts are purer and there is less mud. An analysis of clean crystals from its surface made by E. E. Slosson gave more than 95 per cent of hydrous sodium sulphate. The southern lake is slightly higher than the middle one, but it contains water and is miry. Apparently it does not contain as much soda as the others. According to Slosson's analysis, made in October, 1901, its water is a very strong solution of sodium and magnesium sulphates with some sodium chloride and sodium carbonate. The specific gravity is 1.261.

The following are Slosson's analyses[a] of the waters and salts on material collected by him or W. C. Knight in 1899 and 1901:

Analyses of the Downey Lakes soda deposits.

	1 (1899).	2 (1901).	3 (1899).	4 (1901).	5 (1901).	6 (1901).	7 (1901).
Hypothetical combinations:							
Water	44.41	55.43	74.60	72.79	75.89	49.29	55.94
Insoluble	.11	2.24	....	.13	.02	.51	.10
Sodium sulphate (Na_2SO_4)	28.24	39.17	6.93	12.77	11.50	19.67	41.02
Sodium chloride (NaCl)	.28	.12	1.16	.86	.45	.50	.12
Magnesium sulphate ($MgSO_4$)	26.96	2.24	17.31	13.40	12.08	30.03	1.82
Sodium carbonate (Na_2CO_3)	....	....	....	.05	.06	....	....
Calcium sulphate ($CaSO_4$)	....	.80	....	....	....	....	....
Calculated as dry salts:							
Sodium sulphate (Na_2SO_4)	50.90	92.54	25.61	47.18	47.74	39.18	95.46
Sodium chloride (NaCl)	.50	.28	5.28	3.17	1.86	1.00	.28
Magnesium sulphate ($MgSO_4$)	48.60	5.29	70.11	49.47	50.16	59.82	4.26
Sodium carbonate (Na_2CO_3)	....	....	....	.18	.24	....	....
Calcium sulphate ($CaSO_4$)	....	1.89	....	....	....	....	....

1. Sample of crystallized salts taken under water in middle Downey Lake.
2. From middle lake. Consists of large, clear crystals of mirabilite mixed with mud and water. It was obtained by blasting through the crust to the depth of about 6 feet near the middle of the lake.
3. Sample of the solution standing above the salts represented by No. 1.
4. Solution which filled the blast hole when No. 2 was taken.
5. Water from the southern lake.
6. Sample of crystallized salts found in a small ditch leading out of the southern lake.
7. Sample of the purest crystals obtainable from the extreme north end of the northern lake.

Knight reports tests at the Downey Lakes, where several holes were sunk through the deposit. In the course of a few hours these

[a] Bull. Univ. Wyoming No. 49, 1901, p. 110.

holes were found to have filled with a saturated solution of sulphate of soda, indicating a rate of flow of 450 gallons per hour. The solution was supersaturated and had a gravity of 31° B., containing slightly more than 75 per cent of hydrous sodium sulphate. At this rate, 2½ tons of the anhydrous salt would be obtained every twenty-four hours, if the influx of water into the pits was constant. If the supply is derived from springs, a large amount of soda could be obtained, but if it is due to surface wash, replenishment would be slow.

The Union Pacific Soda Lakes are a group of ponds covering an area of 60 acres in the N. ½ sec. 4, T. 14 N., R. 75 W. The deposit is claimed to be over 12 feet thick and an 8-foot cube of the soda was once taken out. Twenty years ago the deposit was worked to a moderate extent, the product being carried by a branch railroad to Laramie, where it was converted into caustic soda and sodium carbonate. The industry was not profitable, owing, it is stated, to inefficient methods. Later the material was utilized in the glass furnace which was formerly operated at Laramie, but there has been no production since 1895. After the construction of the Pioneer ditch the seepage filled and enlarged the lakes, but doubtless soda still remains on the bottom. Originally the waters had specific gravities from 1.048 to 1.088 and contained the following constituents:

Constituents of waters of Union Pacific Soda Lakes. [a]

[Hypothetical combinations; parts per thousand.]

	Big Lake.	Track Lake.	Red Lake.
Sodium sulphate	44.90	75.63	93.07
Calcium sulphate	1.75	1.46	2.01
Magnesium sulphate	.60	.70	1.43
Magnesium chloride	6.43	3.00	4.16
Sodium carbonate [b]	1.46	1.21	.75
	55.14	52.00	101.42

[a] Pemberton and Trucker, Chem. News, vol. 68, p. 19.
[b] Given as sodium borate, but should probably be sodium carbonate.

An average sample of the deposit gave the following analysis:

Analysis of Union Pacific Soda Lakes deposit.

Water	46.87
Sodium sulphate	34.85
Sodium chloride	1.16
Calcium sulphate	1.45
Magnesium sulphate	.97
Insoluble	13.86
	99.16

The selected crystals and cleanest material had 44 per cent of sodium sulphate, 55 per cent of water, a very small amount of other salts, and less than one-half of 1 per cent of insoluble material. No iron is reported.

The deposits 12 miles north of old Rock Creek station are in an area of Chugwater red beds. There are many small depressions in the region, varying in size upward to 90 acres. They are usually dry or miry except in rainy seasons. The deposit ranges from a thin crust to a bed several feet thick and the composition varies. Ordinarily there is a regular gradation from a preponderance of sulphate of soda on the north to a preponderance of sulphate of magnesia on the south. There is a small admixture of sodium chloride and dirt. According to Slosson [a] the deposits have the following composition:

Chemical composition of the Rock Creek soda deposits.

[Hypothetical combinations.]

	1.	2.	3.	4.	5.
Water	44.50	48.03	51.08	49.66	27.71
Insoluble	.65	.08	1.13	.58	64.96
Sodium sulphate (Na_2SO_4)	12.13	24.49	10.22	40.52	1.20
Sodium chloride (NaCl)	.38	.24	.46	.42	.66
Magnesium sulphate	42.34	27.16	37.11	8.82	5.47

1. From surface of the largest of the lakes.
2. From a depression in a small lake about a quarter of a mile north of the largest.
3. From a large deposit about a mile north of the largest lake.
4. From a deposit just north of No. 3. In this sample the sodium sulphate is between four and five times greater than the magnesium sulphate and it corresponds therefore rather with the ordinary Wyoming soda deposit than with the rest of the deposits of this group.
5. Mud beneath No. 2. The salts contained in it are much the same as in the deposit above, but the proportion of chlorides is much greater.

All these samples were collected by W. C. Knight in February, 1898.

SULPHATE OF MAGNESIA.

The mineral epsomite, or Epsom salts, occurs in several small lake basins 3 miles north of Wilcox station, on the Union Pacific Railroad. The largest lake, known as Brooklyn Lake, has an area of 90 acres and is covered with a deposit of nearly pure Epsom salts. The following analysis has been furnished by Wilbur C. Knight:

Analysis of epsomite from Brooklyn Lake.

Insoluble residue	0.08
Magnesium sulphate [b]	51.22
Water	47.83
Chloride of sodium, calcium, and magnesium	.42
Iron	Trace.
Lost	.45

[a] Bull. Univ. Wyoming No. 49, 1901, p. 114.

[b] Containing a small percentage of calcium and sodium sulphates.

VOLCANIC ASH.

A deposit of volcanic ash is exposed on the south end of a low mesa in the NW. ¼ sec. 6, T. 13 N., R. 73 W., a mile northeast of Sportsman Lake. The section here is as follows:

Section of volcanic ash deposit near Sportsman Lake.

	Feet.
Buff sandstone and conglomerate	1
Volcanic ash	4–5
Red clay	5
Volcanic ash	5
Red shale to bottom of slope.	

The material is a pure white, massive, soft, fine-grained rock which has been prospected under the supposition that it was kaolin and "aluminum ore." Under the microscope it is seen to be volcanic ash. The following analysis shows its composition:

Analysis of volcanic ash near Sportsman Lake.

Silica (SiO_2)	67
Alumina and iron oxide (Al_2O_3, Fe_2O_3)	16
Lime (CaO)	1
Soda (Na_2O)	2.8
Potash (K_2O)	5
Water (by difference)	8.2
	100

The upper bed has been opened in two or three places within a quarter of a mile. It appears to be approximately level and is covered by 1 to 2 feet of sandstone overlain by 3 to 4 feet of gravel. Probably the deposit is not extensive, for it does not outcrop in other portions of the area. Its age is either Quaternary or Tertiary, more probably the latter, though there is no decisive evidence to indicate to which system it belongs.

CEMENT.

Materials for the manufacture of cement exist in large amount in the Laramie Basin, but they have not as yet been utilized. One of the most promising rocks is the impure limestone of the Niobrara formation, which is of wide distribution. The limestones of the Casper, Chugwater, and Morrison formations might also be used mixed with Benton or other shales or alluvial clays to afford the necessary constituents.

SAND.

Large amounts of sand for building and other uses are obtainable from the terraces and alluvial deposits throughout the Laramie Basin. Sand for the glass works formerly in operation at Laramie was procured from very soft sandstone of the Casper formation quarried at a point 3 miles east of the city. The material was nearly pure silica with but a slight trace of iron and a small amount of carbonaceous matter.

CLAY.

The alluvial deposits contain clays, especially in the wide portions of the valleys of Laramie and Little Laramie rivers. The Morrison and Benton formations and the lower part of the Montana consist mainly of clay shales, and the Chugwater formation contains much sandy red clay. Bricks have been made from the alluvial clays at some places, and for the last few years brickworks a short distance west of Laramie have been manufacturing brick from lower shales of the Benton excavated in sec. 36, T. 16 N., R. 74 W. The product is a light reddish yellow brick of very pleasing appearance, which stands a pressure of 5,400 pounds to the square inch. It has been used in several buildings in Laramie, including the new Carnegie Library.

LIMESTONE.

A very large amount of limestone in the Casper formation along the west slope of the Laramie Mountains and in the lower portion of the Chugwater formation can be utilized for flux and lime. Much of the limestone in the Casper formation contains carbonate of magnesia and various impurities, but some of the upper beds are of superior quality; the Forelle limestone also appears to be good in places. Limestone occurs in the Morrison formation in beds from 6 inches to 2 feet thick, but its quality has not been tested. The top limestone of the Casper formation has been worked to a moderate extent in a quarry 2 miles east of Laramie, reached by a spur from the Union Pacific Railroad. At first it was used for glass making at Laramie, but it is now shipped for making lime for beet-sugar refining. The following analysis has been published:

Analysis of Casper limestone quarried 2 miles east of Laramie.

[Analyst unknown.]

Calcium carbonate ($CaCO_3$)	98.83
Magnesium carbonate ($MgCO_3$)	.45
Iron carbonate ($FeCO_3$)	.02
Iron bisulphide (FeS_2)	.10
Alumina (Al_2O_3)	.43
Silica (SiO_2)	.05

COPPER.

Numerous prospect pits are scattered over the outcrop of the Casper formation and the granite east of Boulder Ridge and south of Tie Siding. These have all been sunk in search of copper, largely for the reason that several masses of float native copper weighing as much as 20 pounds have been found. Most of the prospects in the granite have been sunk on diabase dikes which cut that rock and some of which show considerable copper stain. Prospects in the arkose of the Casper formation likewise show much green stain, notably at one place on the King Solomon claim, in the NE. ¼ sec. 15, T. 12 N., R. 73 W., near the contact of the Casper and the granite. A small amount of native copper also occurs here scattered through the arkose, but no lead of promising value has been struck. One of the large chunks of native copper was found near this place. Many pits have been sunk along the fault south of Tie Siding, but without encouraging results.

UNDERGROUND WATERS.

GENERAL CONDITIONS.

The succession and structure of the rocks in the Laramie Basin are favorable for the occurrence of large supplies of underground waters obtainable by wells of various depths. There are water-bearing sandstones in the Casper, Cloverly, Benton, and Montana formations; and water also occurs in the Chugwater red beds, Tertiary deposits, alluvium, and older terrace gravels. As shown in the sections (Pl. VIII), most of the sandstones are widely extended sheets of considerable thickness, interbedded with relatively impervious shales, a condition especially favorable for underground water storage. The sandstones mostly outcrop at high levels, and are carried by their dip toward the center of the basin under shales in areas of lower altitude so that the contained water has considerable head or pressure. Some of the sandstones, notably those of the Casper formation, lie very deep toward the center of the basin, but in this portion of the area water-bearing sandstones of higher horizons are within reach of borings of reasonable depth. The underground waters have not been extensively developed except in the vicinity of Laramie, where numerous flowing wells obtain supplies, mainly from sandstones in the upper portions of the Casper formation. Most other portions of the region are supplied by surface waters or shallow wells obtaining water from the alluvium. The sandstone of the Cloverly formation, which is a most useful source of supply in other regions, has not been drawn upon to any great extent in the Laramie Basin, but a boring for oil near Hutton Lakes has shown that the formation contains water which rises nearly to the surface. The sandstone near the top of the Benton formation, although not very thick, is porous and persistent, so that it may be confidently expected to furnish water. The sandstones of the upper part of the Montana contain large amounts of water, which in some places in the lower lands is no doubt under sufficient pressure to afford flows. These sandstones are the source of water in the artesian well at the Judson ranch on Dutton Creek and in others west of Laramie.

The following table gives a list of the deep borings in Albany County:

Deep borings and wells in Albany County.

Owner.	Location.	Depth (feet).	Yield per minute or height of water.	Quality.
S. W. Downey	SW. corner sec. 4, ½ mile south of Laramie.	201?	2½ gallons	Good.
Do	Sec. 1 or 12, T. 18, R. 78	380	Large	Do.
O. D. Downey	Sec. 4, T. 15, R. 73	170	5 gallons	Do.
Do	do	531	10 gallons	
Plaster Company	Laramie	952	25 gallons	Do.
Oxford ranch	Red Buttes	540	Small flow	Do.
Thomas McHugh	NE. ¼ sec. 5, T. 15, R. 73	112	1 gallon	Do.
Do	NE. ¼ sec. 8, T. 15, R. 73	117	do	Do.
U. P. R. R. sheep pasture.	Sec. 27, T. 16, R. 73, 2 miles northeast of Laramie.	1,001	20 gallons	Do.
J. Simpson	NE. ¼ sec. 5, T. 15, R. 73	112	½ gallon	Do.
Downie ranch	3 miles west of Laramie	400		
G. H. Hunt	Sec. 10, T. 15, R. 73	220	Large; rises to −1½ feet	
G. Montague		150	Small flow	Do.
Paul Pascoe ranch	Mud Springs		Flow	
Ryan Brothers		85	⅓ gallon	Do.
University	Laramie	1,015	35 gallons	Do.
Penitentiary	West of Laramie	(?)		
County	In Laramie	1,500	Large	Do.
Cemetery	Laramie	1,003	4 gallons	Do.
Judson ranch	Sec. 23, T. 19, R. 77	540	5 gallons	Sulphur, poor.
Experimental farm	Laramie			
Mantell ranch			Flowed temporarily	
George ranch (6 wells)	East of Laramie	120-312	Small	Good.
Pelton ranch	SW. corner sec. 10 T. 15, R. 73	333	do	Do.
Bacon ranch (3 wells)			do	
Bell ranch (Millbrook)	Sec. 8, T. 16, R. 76			
J. S. Braskett	Downey addition, Laramie.	100, 125	Small	Do.
Harpers		450	Pumps from −225 feet	Corrosive, and foams.
Homer ranch	Sec. 12, T. 14, R. 74	1,118	Pumps from −4 feet	
Hospital	Laramie	200 or less.	Flowed at first; but now stands at −40 feet.	
Alsop ranch	Sec. 34, T. 17, R. 75	300		
Corthell & Bevans	⅛ mile north of cemetery	313	Small flow	
Haley ranch	Wyoming	89	Rises to −18 inches	
Sherrod addition	Laramie	189	Failure	
Sartoris Willan, home ranch.	Branch of Little Laramie River.	500	Rises to −4 feet	
Mansfield ranch	Sec. 20, T. 14, R. 75	502		Salt.
"Oil well"	Sec. 13, T. 14, R. 75	1,700	Flow	(?)

DESCRIPTION OF WELLS.

Laramie.—There are numerous artesian wells in and near Laramie, most of which yield an abundant supply of water of excellent quality. They vary in depth from 120 to 1,500 feet. The deeper ones draw their supply from the sandstones in the upper part of the Casper formation, which outcrop on the mountain slopes a short distance east of the city. Some others obtain water from sandy portions of the overlying red beds.

The most notable of the wells in Laramie is one sunk about ten years ago at the State university. It reached a depth of 1,015 feet, and obtained a 34-gallon flow of soft water from a depth of 987 feet, and other flows at 458, 820, and 987 to 990 feet. It is reported to have penetrated gray sandstone for the last 200 feet. The original flow was 34 gallons a minute.

The following description of the borings from this well has been compiled from various sources:

Notes on borings from University well at Laramie.

	Feet.
Gravel, sand, and red loam	40
Red sandy clay with a few sandstone fragments	80 120 160 240
Red sand, with some clay and large fragments of gypsum	280
Limestone (Forelle)	310
Limestone and sandstone; first water	458
Pink sandstone	465
Light-pink sandstone; some lime	480
Coarser, darker colored sandstone and lime	505
Pink limestone	546
Dark-red sandstone	570
Red sandstone and limestone	595
Red sandstone; some lime	630 657 698 733
Pinkish sandstone; considerable lime	825 870
White sandy limestone	900 940
White sandstone; some lime	970 995
Light-cream sandstone; some lime	1,015

Materials coarse from 80 to 150 feet; 150 to 300 feet, finer grained and brownish red; 300 to 560 feet, much lighter colored and finer, containing some carbonate of lime; 560 to 590 feet, mottled, coarser, darker, with a little carbonate of lime; 590 to 615 feet, coarse fragments of red sandstone and gypsum; 615 to 650 feet, coarse-grained brown sandstone, containing no gypsum; 650 to 680 feet, coarse sand, with some gypsum; 680 to 780 feet, medium coarse-grained brown sandstone; 780 to 880 feet, very much lighter colored and very fine; 880 to 960 feet, almost white, very fine sand and carbonate of lime; 960 to 1,015 feet, a little coarser than the last and having about the same proportion of carbonate of lime, but of cream color.

There are 40 feet of 7⅝-inch casing to shut off gravel at the top, and 600 feet of 5⅝-inch casing. The first flow was struck at a depth of 458 feet, and comes up between the two casings. The second flow was struck at 820 feet, apparently in the highest sandstone of the Casper formation. The drilling was continued to a depth of 1,015 feet, but no additional water was found below 990 feet. The amount of water flowing at the beginning was measured by B. C. Buffum, and found to be 50,000 gallons in twenty-four hours. An analysis is given on page 76. The contract price for drilling was $2,000, and the university furnished the casing, at a cost of $552.25, making the total cost $2,552.25.

In a well sunk by the county in the SW. ¼ sec. 28, T. 16 N., R. 73 W., just across the road from the western of the two small lakes in the northern part of Laramie, several flows were found, but the main flow was struck at a depth of 987 feet, in the upper part of the Casper formation. A solid 4-inch stream came out under sufficient pressure to jet 20 feet through a 1-inch hole. The upper flows were cut off. No water was found below the flow at 987 feet. The well is cased with 835 feet of 6½-inch casing and 400 feet of 9-inch casing. It is stated by J. J. McCutcheon that the pressure was sufficient to raise the water 60 feet or more above the surface. Apparently no record of this boring is available, but samples from 750 feet to the bottom, 1,500 feet, preserved in the court-house in Laramie, yielded the following descriptive notes:

Notes on borings from county well, Laramie.

	Feet.
Red, fine-grained sandstone with some grains of white quartz, somewhat flaky	750- 927
Pure white sand	927-1,000
Pure white sand with enough red grains to give a slight pink tint	1,000-1,015
Pure buff sand; few flakes of limestone (?)	1,015-1,030
Pure white powder; nearly all dissolves in acid; limestone with a few grains of sand	1,030-1,090
Pinkish, granular, mostly sand; some limestone; contains much carbonate of lime, especially in upper part	1,090-1,195
"Oil sand," "magnetic;" white flakes and chunks $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter; dissolves in acid; limestone; no sand	1,195-1,200
Marked "Highly magnetic lime rock below oil rock and above red sand rock." Chunks ½ inch long, slightly purplish, very fine-grained limestone; effervesces strongly in cold acid. Does not affect the compass needle	1,200-1,215
Marked "Soft red sandstone." Soft, fine-grained, salmon-red powder; considerable fine grit; probably shale	1,215-1,225
Red sandstone, medium grain, coarser than above	1,225-1,235
In part granular, reddish as above; more than half, flat flakes of crystalline limestone; dissolves completely in acid	1,235-1,245
Almost all pinkish fine-grained sand, some few flakes of limestone	1,245-1,315
Almost pure pinkish fine-grained sand	1,315-1,325
Very fine reddish material, probably shale	1,325-1,355
Coarse fragments of quartz and feldspar up to $\frac{1}{16}$ inch in diameter (arkose)	1,355-1,370
Coarse pinkish or reddish quartz sand	1,370-1,400
Perfectly rounded quartz grains, medium fine, one-half white, one-half deep red	1,400-1,415
Sand and chunks of rock consisting of sand grains in a limestone matrix; dissolves partly in acid, leaving loose sand	1,415-1,440
Fine-grained reddish material, probably shale; dissolves slowly and partially in acid	1,440-1,450
Pure white fine-grained sand; effervesces slightly in acid	1,450-1,456
Coarse quartz grains in fine powder which is almost wholly limestone	1,456-1,470
Fine-grained reddish, white, and black plates; the white is lime and dissolves in acid; the black particles may be from the drill	1,470-1,500

At the Acme Plaster Company's plant, in the southeastern part of Laramie, there is an artesian well yielding a 25-gallon flow of soft water, from a depth of 945 feet. The bore is 4½ inches in diameter, cased to 627 feet; the total depth is 952 feet. Some water was found at 600 feet. The following record was supplied by J. J. McCutcheon, the driller:

Record of Acme Plaster Company's well, Laramie.

	Thickness.	Depth.
	Feet.	*Feet.*
Red shale	40	40
Red sandstone	260	300
Limestone	100	400
Soft red sandstone, with gypsum	227	627
(?)	63	690
First flow in red sandstone	....	690
(?)	210	900
Gray sandstone, with water	52	952

The head is sufficient to raise the water 74 feet above the surface.

The first well at the plaster works was about 300 feet deep. It did not flow and the water was of bad quality, owing, it is stated, to faulty casing.

On the ranch of Charles George, in sec. 3, T. 15 N., R. 73 W., in the eastern portion of Laramie, there are six deep wells within a radius of a quarter of a mile. One passed through 90 feet of limestone and found water in sand rock. This well is 5⅝ inches in diameter and the water now stands 18 inches below the top of the casing. On and near the fair grounds, on the south side of the ranch, Mr. George sank two wells in 1888. The one in the grounds is 120 feet deep, entirely in red beds, and, although it yielded a feeble flow at first, the water level is now 6 inches below the top. The water is strongly sulphurous. In another well with 5⅝-inch casing, just outside of the fair grounds, the water rises 8½ inches above the pipe. Two other wells are about 175 yards from Mr. George's house. In one, which is less than 200 feet deep and all in red beds, the water level is about 2 feet below the top; in the other, 30 yards distant, 8 feet higher, and 312 feet deep to limestone, the water level is 6 feet below the top. In the spring the lower of these two wells flows. When the large flowing well is closed the others will flow. The sixth well is in the northeast corner of the stock barn near the house. In this well the water stands 3 feet below the surface, but originally it flowed.

In the southern portion of Laramie there is a group of three flowing wells. One is in the SW. ¼ NW. ¼ sec. 4, T. 15 N., R. 73 W., east of the road. It is 5 inches in diameter and flows approximately 2 gallons a minute of good water with a temperature of 44½°. Its depth could not be ascertained. Another just west of this one, on the Simpson place, in the SE. ¼ NE. ¼ sec. 5, flows less than half a gallon a minute, with a temperature of 45°. Its depth is 112 feet; the water is somewhat saline but is satisfactory for stock. The third well of this group is on the Downey place, near the middle of the south side of the SW. ¼ sec. 4, east of the road, one-half mile southeast of the others. It is 5 inches in diameter and flows about 8 gallons of water that tastes good and has a temperature of 45°. Two wells in the same section, owned by O. D. Downey, are 170 and 531 feet deep and yield flows of 5 and 10 gallons a minute respectively.

In the cemetery at Laramie a well 1,003 feet deep flows about 4 gallons a minute of good water with a temperature of 49°. At the Corthell place, 200 yards north of the cemetery, a well 313 feet deep flows about 1½ gallons a minute; the water is somewhat mineralized, but serves for stock. There is a well at the old penitentiary half a mile west of Laramie; two wells at the experimental farm; and another at a dairy east of this farm; but no data could be obtained regarding any of them.

Union Pacific Railroad.—The Union Pacific Railroad has a deep well in the sheep pasture 2½ miles northeast of Laramie, in the NE. ¼ sec. 27, T. 16 N., R. 73 W. The following record and other data were furnished to W. B. Knight by W. L. Paake, superintendent, in 1904:

Record of Union Pacific Railroad well northeast of Laramie.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	136	136
Red sandstone	8	144
Red shale rock	30	174
Red sandstone	18	192
Red shale	68	260
Red sandstone	5	265
Red shale rock	65	330
Red sand rock	50	380
Hard red sand rock	25	405
Red shale	30	435
Red sand rock	65	500
Red shale	40	540
Red sand rock	18	558
Hard red sandstone	12	570
Soft red sand rock	60	630
Hard red sand rock	25	653
Soft red sand rock	32	685
Hard red sand rock	25	710
Soft white sand rock	15	725
Hard red sand rock	13	738
Hard red shelly sand rock	3	741
Soft sand rock	3	744
Hard red sand rock	5	749
White hard sandstone	10	759
Soft white sandstone	11	770
Red shale rock	10	780
Hard red sandstone	2	782
White limestone	18	800
Hard white sandstone	15	815
Hard white limestone	20	835
Hard white sandstone	12	847
White limestone	24	871
Red sandstone	14	885
Red shale rock	6	891
Hard red sandstone	51	942
Red shale	4	946
Red sandstone	31	977
Hard white rock	13	990
Red sandstone	11	1,001

The boring is cased with 163 feet of 8-inch pipe. A small flow of water was obtained at a depth of 75 feet, additional supplies between 670 and 680 feet, and the main supply at a depth of 744 feet, where the flow increased to 20 gallons a minute. The water-bearing sandstones are in the upper part of the Casper formation.

Pelton ranch.—On the ranch of Charles W. Pelton, in the SW. ¼ sec. 10, T. 15 N., R. 73 W., 2 miles southeast of Laramie, are two deep wells, one sunk in 1889 and the other in 1894. The first is 333 feet deep and entirely in red beds. At 120 feet water was found which rose within 60 feet of the surface; with increased depth the water level rose within 7 feet of the top. The boring ended in quicksand. The water is of good quality, as shown by analysis on page 76, and it is used for irrigating an acre of garden. The second well is 200 yards to the north of the first, and also entirely in red beds. The depth is not given. The well is on a knoll, and the water rises so high that by means of a ditch 3 feet deep a small flow is obtained, which supplies a pond.

Trabing ranch.—At the Trabing place, in the SE. ¼ sec. 25, T. 16 N., R. 74 W., 2 miles northwest of Laramie, there is a well which formerly afforded a good flow, but is now pumped. The depth is not reported. Probably its source of supply is in the red beds.

Downie ranch.—At the Downie ranch, 3 miles west of Laramie, a well 400 feet deep pumps 200 gallons a minute. The main supply is from a depth of 395 feet. The diameter of the inner casing is 5⅝ inches. Water was found also at depths of 60 to 65 feet, 190 to 200 feet, and from 380 feet down. The water level is 20 feet below the surface. The following record is reported:

Record of well on Downie ranch, west of Laramie.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface deposits	20	20
Blue shale (Benton)	160	180
Sandrock, gray, hard, and soft (Cloverly)	220	400

Alsop ranch.—A good pumping well is reported at the Alsop ranch, in sec 34, T. 17 N., R. 75 W. Its depth is 300 feet, and its source of supply is probably the sandstone of the upper part of the Montana group.

"*Oil well.*"—An unsuccessful deep boring for oil was made several years ago near Laramie River, at a point 3 miles west of Hutton Lakes, in the NW. ¼ sec. 13, T. 14 N., R. 75 W. The boring penetrated about 800 feet into the Chugwater formation. The following record was reported from memory by Grant Lee, the driller.

Record of "oil well" 10 miles west of Red Buttes.

	Thickness.	Depth.
	Feet.	*Feet.*
Black shale (Benton)	600	600
Sand and shale (Cloverly)	200	800
Sandy slate	400	1,200
Red caving sandstone	100	1,300
Red sandstone, harder	100	1,400
Red sandstone, much harder	100	1,500
Red sandstone, hard	190	1,690
Hard sandstone, with pebbles	10	1,700

A small amount of water was found at a depth of 90 feet. The second water occurred at a depth of 600 feet, in white sandstone 20 feet thick; it rose within 10 feet of the surface and could not be lowered by bailing. Water was found in many beds between 600 and 800 feet. The lowest water was in 20 feet of brown sandstone at a depth of 1,500 feet; it flowed over the casing.

Mansfield ranch.—On the Mansfield ranch, in the NE. ¼ NE. ¼ sec. 20, T. 14 N., R. 75 W., 16 miles southwest of Laramie, an unsuccessful boring was made in 1890 to a depth of 502 feet. After passing through 9 feet of gravel, dark shale of the Benton formation was entered and continued to the bottom. At 65 feet there was a small flow of salt water, and at 245 feet a small flow of gas. At 440 feet salt water rose within 4 feet of the top of the casing. It is unfortunate that this boring was not continued, for within a short distance it would have entered the Cloverly formation, and doubtless would have obtained good water. To judge by the oil boring in sec. 13 of the same township, however, the pressure is not sufficient to afford a flow.

Homer ranch.—At the Homer ranch on Fivemile Creek, in sec. 12, T. 14 N., R. 74 W., a well 1,118 feet deep yields a fair supply of water which rises within 4 feet of the surface. No record was obtained, but from the thickness of the strata in the slopes to the east it is believed that if this boring had been continued to a depth of 1,250 or possibly 1,300 feet the top sandstone of the Casper formation would have been penetrated and a flow obtained.

Dutton Creek.—On the Empire ranch, in the NE. ¼ NW. ¼ sec. 27, T. 19 N., R. 77 W., there is an artesian well, sunk in 1889, a section of which is given on page 54. The flow is from a depth of 540 feet and amounts to about 5 gallons a minute. The water is cool, but has a somewhat disagreeable taste.

Cooper Creek.—An artesian well on the ranch formerly known as the Northrup place, in the NE. ¼ SW. ¼ sec. 11, T. 18 N., R. 77 W., has a 1-gallon flow from a depth of 272 feet. It is 6⅝ inches in diameter. Water which rose within 12 feet of the surface was found at a depth of 110 feet, but it disappeared at a depth of 180 feet in a cavity into which "the drill dropped 4 feet." The water is cold and of good quality and is derived either from the lower beds of the Tertiary or from a sandstone in the underlying Montana. The material penetrated was reported as "drab shale."

Arlington.—A flow of about 1 gallon a minute is reported from a well of unknown depth in the southwest corner of the SE. ¼ sec. 35, T. 19 N., R. 78 W., 5 miles southeast of Arlington. The water is cold and of good quality and is probably derived from sandstone in the Montana.

SPRINGS.

Springs occur at widely separated localities throughout the Laramie Basin, especially along the slopes at the foot of the mountains. They are the sources of supply for numerous ranches, many of which owe their location to the existence of a spring to furnish water for cattle and house use.

A series of very large springs issues from the limestones at the foot of the Laramie Mountains east and south of Laramie. From one of these, situated in the SE. ¼ sec. 35, T. 16 N., R. 73 W., Laramie is supplied with fine water for drinking and for the irrigation of the lawns, gardens, and numerous trees that make the city appear like an oasis. The water, which issues 114 feet higher than the city, is conducted into covered reservoirs and thence piped to the consumers. The analysis, given on page 76, shows that it is somewhat hard, but this can be remedied by boiling or the use of lime water. Its volume is estimated at 3,000,000 gallons a day.

Four miles due south of this spring is another similar but smaller one which supplies Soldier Creek and from which the fish hatchery obtains an abundant supply of cool water. (See Pl. VII, *B*.)

Springs at the J. Simpson ranch, 2½ miles farther south, also supply good water in large volume.

Mud Springs, at the foot of Laramie Mountain 6 miles northeast of Wyoming station, are the source of a running stream of moderate size.

A spring situated in Spring Canyon, 1 to 2 miles east of Colores station, on the Union Pacific Railroad, supplies water of fine quality, which is piped to the tank at the station. Its flow keeps a 4-inch pipe nearly full.

McGibbons Spring, in the SE. ¼ NE. ¼ sec. 29, T. 14 N., R. 73 W., supplies a large fish pond, the overflow of which forms a considerable addition to Willow Creek.

Willow Spring rises in a grassy, willowy quagmire several acres in extent in sec. 15, T. 13 N., R. 73 W. Its total discharge is between one-half and 1 second-foot and the quality of its water is good.

Sybille Springs, in Plumbago Canyon 8 miles east of Lake Ione, are the principal source of supply for Sybille Creek.

Rice Spring is situated in the S. ½ sec. 26, T. 13 N., R. 75 W. It flows from the Chugwater formation not far above the gypsum horizon. The water at the spring is good and it is used for domestic and stock purposes. Half a mile or so below the spring the stream becomes so badly contaminated with gypsum that fish can not live in it, though they thrive near the spring.

Boswell Spring, located in sec. 31, T. 23 N., R. 74 W., rises in red beds near the top of the Casper formation; the quality of the water is good and the flow is about one-third cubic foot.

Water of notable purity is found in a spring on Ernest Davis's ranch near Sheep Mountain; an analysis is given below.

In the southeastern part of sec. 14, about a mile north of Soldier Springs, a spring of soft water issues from a dark-red limy sandstone. Formerly this spring supplied a small pond and running stream, but now the water level is several feet below the surface. A small lake, which formerly existed on the NE. ¼ sec. 14, a mile southeast of the fair grounds, dried up at the same time that the water level fell in the spring, indicating a change in underflow conditions.

A large spring of pure mountain water breaks out on the J. J. Hays ranch, on the western margin of the Centennial Valley. It flows away in a stream 2 feet deep and 3 feet wide and is the chief source of Middle Fork of Little Laramie River.

WATER ANALYSES.

The following are the available analyses of the waters of the Laramie Basin:

Analyses of waters in Laramie Basin.[a]

[Parts per thousand.]

	1.	2.	3.	4.	5.	6.
Silica	0.0072	0.0257	0.0087	0.0163	0.0388	0.0674
Iron and alumina	.0015	.0014	.0040	.0008	....	.0048
Potash	.0014	.0102	.0012	.0023	.0176	.0022
Soda	.0085	.0196	.0047	.0133	.6471	.0210
Lime	.0432	.2660	.0668	.0643	.3280	.0411
Magnesia	.0094	.1060	.0260	.0361	.2896	.0083
Sulphuric acid	.0106	.4380	.0053	.0129	1.7361	.0197
Carbonic acid	.0608	.1032	.1474	.1326	.0620	.0428
Lithia	....	....	Trace.	Trace.	.0041	....
Hydrochloric acid	....	....	.0042	.0137	.0834	.0066
			.2683	.2923	3.2067	[b].3889
Less O equivalent of Cl	....	....	.0010	.0031	.0188	.0015
Total solids	.1426	.9701	.2673	.2892	3.1879	.3874

[a] Slosson, E. E., Bull. Univ. Wyoming, Nos. 24, 45.

[b] Including 0.1750 insoluble.

Analyses of waters in Laramie Basin—Continued.

HYPOTHETICAL COMBINATIONS.

[Grains per gallon.]

	1.	2.	3.	4.	5.
SiO_2	0.420	1.499	0.507	0.950	2.263
Fe_2O_3 and Al_2O_3	.087	.082	.233	.047	....
KCl	....	....	.111	.210	1.627
Na_2SO_4	.974	2.612	.233	.373	79.333
Mg_2SO_4	....	18.544	.274	.810	50.665
$CaSO_4$	....	19.063	....	....	38.739
$CaCO_3$	4.496	13.676	6.951	6.695	5.674
K_2SO_4	.152	1.096	....	....	....
Na_2CO_3	.117	....	....	....	....
$MgCO_3$	1.149	....	2.986	3.855	....
CO_2	.921	....	3.977	2.770	1.120
NaCl	....	....	.315	1.155	5.796
LiCl	....	....	....	....	.688
Total solids	8.316	56.572	[a]15.587	16.865	185.905

[a] Trace of lithia.

1. Davis Spring, near Sheep Mountain.
2. Pelton well, sec. 10, T. 15 N., R. 73 W.
3. Laramie Springs, 2 miles east of Laramie (city water), August 31, 1892.
4. University well, Laramie.
5. Fein well, 1½ miles west of Laramie (58 feet deep; lithia water).
6. Laramie River, Pioneer canal at experiment farm, 20 miles below intake (average analyses, 1894 and 1895).

INDEX.

O