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

GEOLOGIC ATLAS
OF THE
UNITED STATES

LARAMIE-SHERMAN FOLIO

WYOMING

BY

N. H. DARTON, ELIOT BLACKWELDER,
AND C. E. SIEBENTHAL

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds—(1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

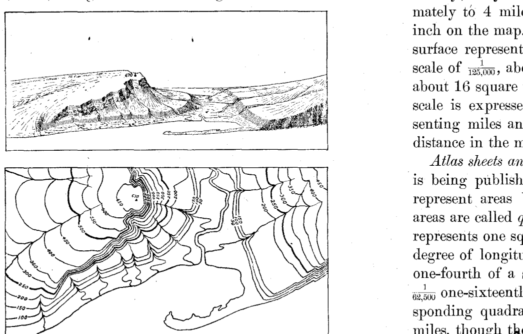


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations, so far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits of these are called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the kinds of deposit named may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which rocks were made is divided into *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by the name of the time interval in which it was formed.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. Where two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent Pleistocene	Q	Brownish yellow.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Ꞓ	Brick-red.
	Algonkian		A	Brownish red.
	Archean		Æ	Gray-brown.

SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterward partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

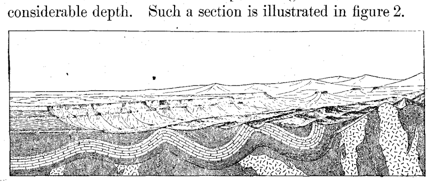


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

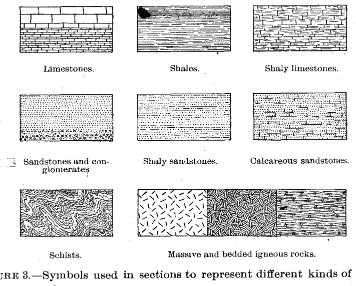


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

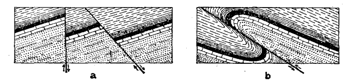


FIGURE 4.—Ideal sections of strata, showing (*a*) *normal* faults and (*b*) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists were metamorphosed, they were disturbed by eruptive activity, and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

The intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

GEORGE OTIS SMITH,
Director.

May, 1909.

DESCRIPTION OF THE LARAMIE AND SHERMAN QUADRANGLES.

By N. H. Darton, Eliot Blackwelder, and C. E. Siebenthal.

GEOGRAPHY.

By N. H. Darton.

POSITION AND EXTENT OF THE QUADRANGLES.

The Laramie and Sherman quadrangles embrace the half of a square degree that lies between parallels 41° and 41° 30′ north latitude and meridians 105° and 106° west longitude. They measure approximately 35 miles from north to south and 53 miles from east to west and their total area is 1797 square miles. They comprise part of the southwestern portion of Laramie County and most of the southern third of Albany County, Wyo. Their geographic position is shown in figure 1.

The quadrangles include a portion of the Laramie Mountains, the northern prolongation of the Front Range of the Rocky Mountains. The Laramie quadrangle lies mainly in the Laramie Basin, one of the great intermontane valleys, and the eastern third of the Sherman quadrangle comprises a portion of the Great Plains.

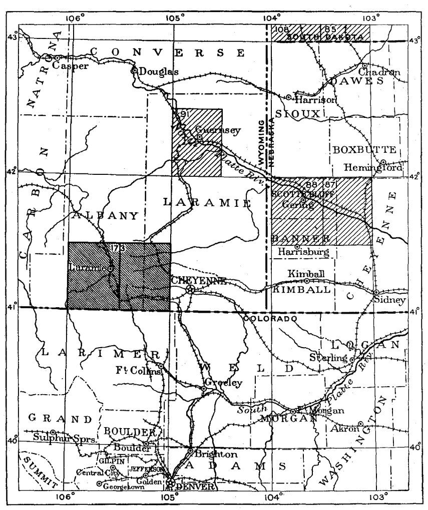


Figure 1.—Index map of vicinity of Laramie and Sherman quadrangles, Wyoming.

Scale, 1 inch=50 miles.

Darker ruling, area of Laramie and Sherman quadrangles. Other published folios indicated by lighter-ruled areas, numbered as follows: 85, Oelrichs; 87, Camp Clark; 88, Scotts Bluff; 91, Hartville; 108, Edgemont.

Being part of the Rocky Mountains and the Great Plains, these quadrangles illustrate many features of both. Accordingly a general account of these provinces will be presented before the detailed description of the quadrangles is given.

ROCKY MOUNTAIN PROVINCE.

Relief.—The high mountain chain known as the Rocky Mountains rises abruptly from the Great Plains, from altitudes of 4000 to 6000 feet above sea level at its foot to a general elevation of 10,000 feet, though many scattered summits attain heights ranging from 11,000 to over 14,000 feet. The Rocky Mountain province consists of numerous ridges, differing in width and length but most of them extending for several hundred miles in a course that lies approximately north and south. These ridges are due mainly to anticlinal uplifts of pre-Cambrian granites, schists, and other rocks and of the overlying Paleozoic strata. The most prominent ridge, known as the Front Range, extends from Arkansas River in Colorado northward far into Wyoming, where it is known as the Laramie Mountains. Next west is a long valley, of irregular width and altitude, which in Wyoming, where it widens and deepens considerably, is known as the Laramie Basin. Farther west are many high ridges, one of which in its northern extension, known as the Medicine Bow Mountains, rises on the west side of the Laramie Basin. In central Wyoming the Rocky Mountains are extremely irregular, as the range is crossed and offset by areas of high plains and plateaus, one of which merges into the north end of the Laramie Basin. The Bighorn Mountains, an outlying hook-shaped range, are united to the Shoshone Mountains by the lower Bridger Range and the Owl Creek Mountains. The Wind River Mountains, which may be regarded as the principal representative of the Rocky Mountains in central Wyoming, give place farther south and southeast to low, scattered ranges, composed largely of pre-Cambrian rocks, with interspersed areas of Tertiary plains, which extend nearly to the northwestern extremity of the Laramie Mountains on one hand and to the north end of the Medicine Bow Mountains on the other. The Black Hills, which form an outlier of the Rocky Mountains, rise about 3000 feet above the surrounding Great Plains.

Drainage.—The Rocky Mountain province marks the divide between the waters of the Atlantic and those of the Pacific Ocean, but the line of separation lies some distance west of the front ranges. The Missouri, rising in Montana, and the Rio Grande, rising in central Colorado, are the principal streams. The Arkansas also rises in central Colorado, where it drains a wide area of high mountains. It cuts a deep gorge through the second of the eastern ranges. The North Platte, which drains a large mountain area in northern Colorado and central Wyoming, flows around the north end of the Laramie Mountains. Laramie River, which is one of its larger branches, rises in the mountains of northern Colorado and crosses both the Laramie Basin and the Laramie Mountains. The high mountains of north-central Wyoming are drained by Wind and Bighorn rivers, branches of the Yellowstone, which empties into the Missouri in Montana.

GREAT PLAINS PROVINCE.

General features.—The Great Plains province is that part of the continental slope which extends from the foot of the Rocky Mountains eastward to the valley of the Mississippi, where it merges into the prairies on the north and the low plains adjoining the Gulf coast and the Mississippi embayment on the south. The plains present wide areas of tabular surfaces, traversed by broad, shallow valleys of large rivers most of which rise in the Rocky Mountains, and cut more or less deeply by the narrower valleys of lateral drainage ways. Smooth surfaces and eastward-sloping plains are the characteristic features of the province, but in some parts of it there are buttes, extended escarpments, and areas of badlands. Sand hills surmount the plains in some localities, notably in northwestern Nebraska, where they occupy an area of several thousand square miles. The province is developed on a great thickness of soft rocks, sands, clays, and loams, in general spread in thin but extensive beds that slope gently eastward with the slope of the plains. These deposits lie on relatively smooth surfaces of the older rocks. The materials of the formations were derived mainly from the west and were deposited, layer by layer, either by streams on their flood plains or in lakes and, during earlier times, in the sea. The strata show but few local flexures, as the region as a whole has been alternately uplifted and depressed and not subjected to folding. During earlier epochs the surface was even smoother than at present. Owing to the great breadth of the plains and their relatively gentle declivity, general erosion has progressed slowly notwithstanding the softness of the formations; and as at times of freshet many of the rivers bring out of the mountains a larger load of sediment than they can carry to the Mississippi, they are now locally building up their valleys rather than deepening them.

Altitudes and slopes.—The Great Plains province as a whole descends to the east about 10 feet in each mile from altitudes approaching 6000 feet above the sea at the foot of the Rocky Mountains to about 1000 feet near Mississippi River. The altitudes and the rates of slope differ considerably in different districts, particularly to the north, along the middle course of Missouri River, where the general level has been greatly reduced. The Great Plains rise to an altitude of 6200 feet at the foot of the Rocky Mountains, west of Denver, and maintain this elevation far to the north, along the foot of the Laramie Mountains. High altitudes are also attained in Pine Ridge, a great escarpment that extends from a point near the north end of the Laramie Mountains eastward through Wyoming, across the northwest corner of Nebraska, and for many miles into southern South Dakota. Pine Ridge marks the northern margin of the higher levels of the Great Plains and presents cliffs and steep slopes descending a thousand feet into the drainage basin of Cheyenne River, one of the most important branches of the Missouri. From this basin northward there is a succession of other basins with relatively low intervening divides, which do not attain the high level of the Great Plains to the south.

Drainage.—The northern portion of the Great Plains above described is drained by the middle branches of Missouri River, of which the larger members are Yellowstone, Powder, Little Missouri, Grand, Cannonball, Owl, Cheyenne, Bad, and White rivers. On the southern slope of Pine Ridge not far south of the escarpment is Niobrara River, which rises in the midst of the plains some distance east of the north end of the Laramie Mountains. Farther south are Platte River, with two large branches heading far back in the Rocky Mountains, and Arkansas River, both of which cross the plains to the southeast and afford an outlet for the drainage from a large area of mountains and plains. South of the Arkansas are Cimarron River and numerous smaller streams that head in the western portion of the plains. Between Arkansas and Platte rivers is Republican River, rising near the one hundred and fifth meridian, and an extensive system of local drainage in eastern Kansas and Nebraska.

RELIEF OF THE QUADRANGLES.

The Laramie and Sherman quadrangles occupy a region that presents great diversity of relief. It includes high mountains and ridges, wide plains and valleys, extensive terraces and mesas, canyons of moderate depth, and basins of various kinds. At the west are the spurs of the Medicine Bow Mountains; east of them the wide, relatively level Laramie Plains, extending to the high, broad ridge of the Laramie Mountains, from the foot of which the Great Plains stretch far to the east. The history of the development of these features will be considered under "Geologic history."

The topographic features are closely related to the lithologic character and distribution of the rocks. The mountains are due to the pre-Cambrian granite and schist and the flanking ridges to hard sandstone and limestone. The valleys are excavated in shales and in soft thin sandstones, and the Great Plains are developed on soft sandstones, sandy clays, and deposits of sand and gravel lying on shale and soft sandstone.

Laramie Mountains.—The most prominent topographic feature in the area is the range called the Laramie Mountains, an elevated plateau rising about 1500 feet above the adjoining Laramie Plains. Its altitude above sea level ranges from 8000 to 8500 feet in greater part, although some of the summits are higher, notably Crow Creek Hill, 8877 feet, and Pilot Knob, 8850 feet. The outlying Pole Mountain rises a little above 9000 feet. The mountain plateau is neither level nor smooth; it slopes up to the central divide, it is cut by many canyons, and out of it rise many knobs and short ridges. Still, when viewed from a commanding point, a wide area, especially of the granite surface, will be seen to fall into a remarkably even plain tilted slightly to the east. In many local areas between the streams the land is smooth or but gently rolling and the ridges have rounded summits. Such areas are especially well marked on the divides between Crow, Lodgepole, and Horse creeks. They are remnants of a nearly smooth plain, worn almost level by long-continued denudation. A few rugged hills, such as the Sherman Mountains and Raggedtop Mountain, which rise above this old surface, were not entirely worn away by the denudation. The old plain extends across granites and schists, and although the different rocks present slightly different details of topography—here smooth and rounded, there ragged and uneven—all are equally worn down to the same general level. The rocks are deeply rotted, so that thick residual detritus mantles the old surface wherever it is well preserved. In the granite areas the soil is a coarse feldspathic gravel; on the gneisses and schists it is sandy or loamy, according to the composition of the underlying rocks. The surface of the upland is not strictly plane, but its undulations are inconspicuous. Shallow depressions, some of them seemingly the work of wind, alternate with broad, low swells. Areas representing the old plain may be seen west and southeast of Twin Mountains.

The main Laramie Mountain divide, which passes from north to south along the west side of the Sherman quadrangle, is throughout the greater part of its course a distinct ridge of sandstone and limestone, presenting to the east a cliff 50 to 200 feet high and sloping down on the west to the Laramie Basin;

near Laramie it has made a total descent of over 1500 feet. This long western slope accords closely with the dip of the strata in that direction. But few stream gaps break its evenness, and in this respect it presents a marked contrast to the eastern slope.

The eastern slope of the Laramie Mountains descends abruptly to a line of foothill ridges made up mostly of hard limestone and sandstone. (See fig. 11, illustration sheet.) These ridges are specially prominent north of Crow Creek, where they rise high between the numerous canyons of creeks that flow eastward out of the highlands. The ridges are narrow because the hard rocks are vertical, but one of them widens in Mesa Mountain, where the angle of dip decreases. South of Crow Creek the foothill ridge is interrupted by many broad overlaps of Tertiary deposits, and from Granite Canyon southward these deposits rise so high on the mountain sides that the slope from the plains to the highlands is fairly uniform. By means of this slope the Union Pacific Railroad gains an altitude of 7300 feet before entering the granite area.

Great Plains.—The region lying east of the Laramie Mountains is a typical portion of the Great Plains of the middle western United States. These plains present wide areas of smooth-surfaced lands that slope gently to the east and are traversed by broad valleys, most of them with gentle side slopes. Local buttes and badlands give considerable diversity to the landscape along some of the valleys. The region is underlain by a great thickness of soft rocks—shale, sandstone, and sand—in large part lying nearly horizontal. In the southeast portion of the Sherman quadrangle these plains rise from 6500 to 7400 feet above sea level, extending far up the slope of the mountains. Crow, Lodgepole, Horse, and Chugwater creeks have cut deeply into them near the foot of the mountains north of Granite Canyon, so that their western margin is a westward-facing escarpment, as shown in figure 5 (illustration sheet). This escarpment, which is 200 to 500 feet high, is a prominent feature on the divides and along the sides of the valleys of the creeks mentioned. Its western edge is about 3 miles from the foot of the mountains and the valley at its base is traversed by the Colorado and Southern Railroad. In this valley are low ridges and buttes and local badlands that extend to the limestone and sandstone ridges of the narrow foothill range.

Laramie Basin.—The Laramie Basin, generally known as the "Laramie Plains," is a wide, rolling plain lying between the Laramie Mountains on the east and the Medicine Bow Mountains on the west. Its altitude varies from about 7000 feet in its northern and central portions to 7500 feet near the Colorado boundary, where it narrows into a valley that rises into a high divide between the mountains. The basin is 90 miles long and about 30 miles wide at its widest part. The Laramie Mountains rise on the east side of the basin in a long, gentle slope, as described above, but the mountains on the west are very steep and the continuity of their front is interrupted by some high outlying masses, of which Jelm and Sheep mountains are especially prominent. These steep slopes are due to great faults.

The Laramie Basin consists mostly of broad, shallow, terraced valleys separated by low, flat-topped ridges which are remnants of an earlier terrace system. The valleys of the Little Laramie and main Laramie rivers are especially wide and flat bottomed. A characteristic view of the valley of Little Laramie River is shown in figure 4 of the illustration sheet. The divide between these two valleys west of Laramie is a broad ridge 200 feet or more high, containing a depression 300 feet deep known as the Big Hollow. It is 9 miles long and 3 miles wide, 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. Both depressions are somewhat deeper than the valleys to the north and south. They are excavated in Cretaceous shale, which is capped by terrace gravels. There are many other similar but smaller basins, one of which is occupied by James Lake.

The topography of the southern part of the Laramie Basin presents considerable diversity. Boulder Ridge is a prominent granite range projecting into the basin from the south and rising 600 to 1000 feet above the valleys on its sides. Red Mountain, a pile of nearly horizontal strata extending from the Chugwater to the Cloverly formation, rises over 1000 feet above the Shell Creek valley, near the Colorado state line. Several ridges of moderate prominence mark the course of the Cloverly formation on the slopes between Ring Mountain and the Downey Lakes.

Medicine Bow Mountains.—The Medicine Bow Mountains, which extend along the west side of the Laramie Basin, form a northern extension of one of the main ranges of the Rocky Mountains; in their central part, called the Snowy Range, they reach an altitude of 12,005 feet. The main body of these mountains lies outside of the Laramie quadrangle, but the outlying ridges, known as Sheep and Jelm mountains, are included within it. Jelm Mountain, which has an altitude of 9665 feet, is separated from the main range by a gorge cut by Laramie River. Ring Mountain, 8805 feet high, is a spur of Jelm Mountain. The greater part of Sheep Mountain, which in one summit reaches the height of 9590 feet, is separated from the Medicine Bow Mountains by Centennial Valley, a narrow basin 7600 to 8000 feet in altitude.

DRAINAGE OF THE QUADRANGLES.

The Laramie quadrangle is drained by Laramie River. The greater part of the Sherman quadrangle lies on the headwaters of branches of Horse and Chugwater creeks, which flow into the North Platte, and of Lodgepole, Crow, and Dale creeks, which empty into the South Platte. Thus the entire drainage of this area passes into Platte and Missouri rivers and empties into the Gulf of Mexico.

The greater part of the Laramie Basin is traversed by Laramie River and its branches, a stream which rises in the Medicine Bow Mountains and other ranges in northern Colorado, receives various branches from the south and west, crosses the Laramie Mountains 30 miles north of the quadrangles in a deep canyon, and flows out across the Great Plains to join the North Platte. Little Laramie River is its principal branch, flowing in from the west, and Sand, Willow, and Fivemile creeks are other tributaries of moderate volume. Laramie River receives but few branches from the east and south, the principal ones being Sand, Willow, Soldier, and Spring creeks, which carry small volumes of water.

A notable feature in the Laramie Mountains is their general drainage toward the east, down the long eastern slope of the range. The principal streams of this slope are the various branches of Crow, Lodgepole, and Horse creeks, which carry fair volumes of water derived from many springs in the mountains. Dale Creek is a similar stream flowing into Colorado, to South Platte River. The southernmost prongs of Chugwater Creek, which drain the northern part of township 17, are small running streams. Lonetree, Duck, and Goose creeks, which have very small drainage areas on the east slope of the mountains, sink into sands of the Arikaree formation a short distance east of the mountains except at times of heavy rains. All the small streams that rise on the plains are intermittent, and many of them are completely dry in summer except at a few "water holes."

The streams present much variation in grade and in the character of their valleys. Where the rocks are soft, as in the Laramie Basin and in the plains, or deeply rotted, as on top of the Laramie Mountains, the grades are low and the valleys are wide and shallow. On the mountain slopes and ridges, where the rocks are hard, the streams are rapid and the valleys are mostly deep, narrow canyons. Such canyons are especially notable on the east side of the Laramie Mountains, where the streams cross the ridge caused by the Casper formation in deep rocky gorges. The depth of these gorges is due to the proximity of the lower lands of the plains. Farther upstream, where the volume of water is less and the rocks are deeply rotted, the valleys are wide and in places contain considerable alluvium.

CLIMATE OF THE REGION.

The climate of the Laramie-Sherman region presents the usual features of that of the northern Rocky Mountains and the higher Great Plains. It is dry and cool, relatively uniform from year to year, and is notable for a large amount of sunshine. Meteorological records have been kept at the State University at Laramie since 1891 and the results are given below.

Monthly mean temperature in degrees Fahrenheit at Laramie, Wyo., 1891–1905.

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

Mean for the year, 40.3.

Extremes of temperature and mean annual temperature at Laramie, Wyo., 1891–1908.

Year.	Highest.		Lowest.		Mean for the year.
	Deg. F.	Date.	Deg. 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
1906	88	Aug. 16	—19	Mar. 16	44.6
1907	85	Aug. 4	— 9	Dec. 19	41.8
1908	86	Aug. 9	—24	Nov. 14	40.4

It will be seen from this table that the temperature rarely reaches 90° F. and that the periods of higher temperature are of short duration. Owing to the great dryness of the air, the heat is not oppressive. The nights are cool, the temperature falling rapidly after sunset. The lower winter temperatures do not continue long but recur in irregular cycles separated by several days of more moderate temperature. Heavy winds may accompany a cold wave or a thunder storm.

The average yearly precipitation at Laramie is 9.9 inches. The monthly averages and the annual precipitation for fifteen years are shown below.

Monthly mean precipitation at Laramie, Wyo., in inches.

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

Annual precipitation at Laramie, Wyo., in inches.

1891	13.92	1897	12.48	1903	10.37
1892	12.73	1898	7.63	1904	9.58
1893	3.84	1899	11.84	1905	9.76
1894	7.63	1900	8.53	1906	12.57
1895	11.15	1901	8.52	1907	9.46
1896	12.80	1902	7.73	1908	13.02

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 damage to crops.

GEOLOGY.

DESCRIPTION OF THE ROCKS.

PRE-CAMBRIAN ROCKS.

By Eliot Blackwelder.

GENERAL STATEMENT.

Occurrence.—In the country about Laramie the oldest rocks whose age has been determined are the Pennsylvanian ("Upper Carboniferous") limestones and shales. Beneath these, and separated from them by a pronounced unconformity, lies a mass of igneous and metamorphic rocks which are evidently very much older but which yield no fossils or other indications of their exact age. These ancient rocks are exposed only where the arching of the sedimentary beds, followed by erosion, has brought them to the surface, namely, in a broad belt running north and south through the Sherman quadrangle and in several isolated patches in the Laramie quadrangle. All of these are really northward extensions of a much larger area of similar rocks in the adjacent parts of northern Colorado.

Kinds of rocks.—This ancient foundation of the sedimentary strata is a complex, consisting of many varieties of rocks of different modes of origin. Most of these are igneous rocks, some of which have been highly metamorphosed. In a few localities metamorphic sedimentary rocks have been detected, and there are some other varieties whose origin is doubtful. The rocks are of many different ages. The oldest have been folded and metamorphosed and others have been intruded into them later without being themselves deformed. The most widespread of all these formations is the Sherman granite—one of the younger intrusives. This has so broken and separated the preexisting mass of rocks that they are now found only in irregular patches, surrounded by and apparently resting upon granite which has welled up from below.

Age.—Since all these rocks lie unconformably beneath the Pennsylvanian ("Upper Carboniferous") series, it is clear that they are pre-Carboniferous in age. In the Bighorn Mountains, the Black Hills, and other uplifts not far distant similar rocks lie beneath the Cambrian strata. There the Cambrian and Carboniferous are part of a nearly continuous sequence of rocks, which were deposited during a single great era of submergence and have never been greatly disturbed since. They began to be deposited not only after the metamorphic and volcanic processes which produced the ancient rocks had ceased, but after all of those rocks had been eroded to great depths during a long period of quiescence. It is therefore reasonably certain that the rocks now under consideration are much older than the Cambrian.

There are less firm grounds on which to assign these rocks to specific periods within the great pre-Cambrian eon. In that the oldest of the formations in these two quadrangles consists largely of metamorphosed volcanic rocks intruded by gneisses the rocks resemble the Archean system of the Lake Superior region and some other parts of North America. In the Laramie district, however, we find no trace of a great sedimentary series comparable to the Belt series of Montana and the other Algonkian strata of the Rocky Mountain province. On the contrary, the rocks here are very much like the igneous complex which lies beneath those sediments where they have been found. Farther north, in the Laramie Mountains, and farther south, in Colorado, there are metamorphosed sedimentary rocks which seem to belong to this complex. They are provisionally referred to the Algonkian system. It therefore seems reasonable to conclude that the pre-Cambrian rocks of the

Sherman and Laramie quadrangles are in part of Archean and in part of Algonkian age.

SCHIST AND GNEISS.

General character and distribution.—The oldest rocks in the district are certain dark schists and gneisses, which are exposed chiefly in the southwestern part of the Laramie quadrangle and the northern and southern parts of the Sherman quadrangle. Owing to the fact that they have been intricately intruded by many later igneous rocks their outcrops are very irregular in outline and patchy in distribution.

When examined in detail this ancient series discloses a large number of rock varieties, some intruded into others or lying in alternating beds and all so highly folded and metamorphosed that it is difficult to ascertain their structure, origin, and inter-relations. The most abundant rocks are dark-greenish hornblende schists, or amphibolites, which are apparently metamorphosed basic dikes and lava flows. With these are found acidic eruptive rocks, such as schistose rhyolites and felsites, as well as soft mica schists, contorted mica gneisses, and many others. Rocks resembling highly altered limestones and quartzites are occasionally found in the twisted complex of igneous derivatives but they are rare, and the identification of them is open to question.

Jelm Mountain area.—Banded hornblendic schists predominate in the slopes of Jelm Mountain. They show many variations in texture and color; some are massive, others slaty; some black and glistening, others gray because rich in quartz.

Under the microscope an average specimen of the hornblendic schist shows green hornblende mingled with feldspar and quartz. The light-colored minerals are usually more abundant than the dark, but the latter have the greater effect on the general color of the rock. The feldspars vary from orthoclase and microcline to labradorite, all three being found in some of the rocks. On the whole, sodic feldspars predominate. In form all the crystals are allotriomorphic, or irregular, the quartz and feldspar occurring as grains and the hornblende as rough prisms. The rude parallel arrangement of the grains is best observed on the broken surfaces. It is not sufficiently perfect to produce good cleavage. All of the constituents have recrystallized, and in the process there have doubtless been chemical changes. To judge from similar rocks elsewhere, the origin of which has been determined, these schists may have been derived from basic igneous rocks, such as basalts and diabases, composed of lime feldspar and pyroxene. Other origins, however, are not precluded by anything observed in these specimens.

With these rocks mica schists are intimately associated. The north slope of Jelm Mountain shows them to the best advantage. They are banded gray muscovitic schists, some being highly quartzose, while in others the mica largely predominates. The micaceous variety is soft and disintegrates readily. The origin of these schists can not be stated with confidence, for either sedimentary or igneous rocks may under proper conditions produce such varieties. The relation between the mica schists and the hornblendic rocks with which they are so intimately mingled is obscure, but certain of the hornblendic gneisses seem to occur as dikes intrusive in the schists.

Twin Mountains area.—The largest exposure of the most ancient rocks is in the Sherman quadrangle, in the vicinity of Twin Mountains, and extends thence northeastward. Here again the prevailing rocks are greenstones or banded hornblende schists and gneisses, of greenish and gray colors. The origin of these rocks is not clearly apparent, but they closely resemble greenstone schists, which in some other parts of the world have been proved to be metamorphosed basic lavas.

The hornblende schists are identical with those of Jelm Mountain, already described. A greenstone on the east slope of the hill south of Haygood's ranch, however, is interesting in that it furnishes a clue to the origin of the greenstones of the district in general. It is a dense gray-green rock in which no minerals can be seen with the unaided eye. The etching of the atmospheric agents, however, brings out a parallel fibrous structure which the microscope shows is due to the linear arrangement of quartz and hornblende, both in very minute crystals. Here and there minute crystals of lime feldspar, partly replaced by quartz, are set in eye spots about which the lines of hornblende swerve. These feldspars are believed to be the only original portions of the rock now remaining. The fibrous mass of quartz and hornblende has probably been produced by the recrystallization, under pressure, of a massive basic rock. It may be suspected that the greenstone was once a dense basalt which carried minute phenocrysts of plagioclase.

Bedded structure observed south of Hecla may mean that the rocks are actually old flows which were poured out upon the surface. The occurrence of greenstones south of Gunson in the form of irregular dikelike bodies traversing rocks of a different character indicates, however, that some of them are intrusions.

South of Gunson's and Haygood's ranches the green schists are associated with other schistose rocks which are more acidic in composition. They are hard steel-gray, buff-gray, or even pinkish rocks, with dense or slightly porphyritic texture. Microscopic examination shows that they are fine-grained felsites or rhyolites which have been rendered schistose. They form a highly inclined series with alternating bands of color. Possibly this is a sequence of acidic lava flows, corresponding to the basic flows now represented by the hornblende schists. The presence of fragmental breccia schists and amygdaloids in the series lends additional plausibility to the idea that they are surface volcanic products. Some of these rocks occur also in the form of dikes which cross certain of the hornblende schists. It is probable that the hornblendic rocks and schistose rhyolites together represent an alternation of basic and acidic flows and breccias belonging to a single period of volcanic activity. The dikelike bodies of rhyolite schist and greenstone schist may then represent conduits leading to the later acidic and basic flows, respectively, but cutting some of the older flows.

In detail the siliceous schists are varied. Some are light gray, some are purplish, and others are nearly black. Fine parallel streaks and indistinct spots are characteristic, yet some are massive and wholly without schistose structure. Almost all are hard, because highly quartzose, and they therefore have a tendency to form low, ragged ledges in the otherwise smooth surface; but the district has been so thoroughly worn down that few rocks build notable ridges.

The microscope shows that most of these schists consist of finely granular quartz and alkali feldspar with small flakes of either mica or hornblende. Biotite is more abundant than muscovite. Little grains of magnetite are abundantly distributed through some of the rocks, and to these are due the darker shades of the gray color. Epidote and chlorite are common in the hornblendic varieties and locally form green streaks that are visible to the naked eye. Little phenocrysts of pink soda feldspar and quartz are visible under the microscope and on weathered surfaces. Most of them have been altered to muscovite, quartz, and secondary feldspar, and in the distinctly schistose varieties they are granulated and mashed out into lenses. That the less altered varieties are felsitic or rhyolitic rocks is obvious from their microscopic features. From these to quartz-mica schists all gradations may be found, so that all appear to have been similar originally.

Rocks which appear to be volcanic breccias and amygdaloids are associated with the schistose rhyolites. The former contain abundant fragments essentially like the siliceous matrix in which they are embedded. During the mashing of the rock each fragment has been squeezed into elliptical form and the lenses that were thus produced now lie parallel to the schistose structure.

With these demonstrably igneous rocks, bodies of banded and highly contorted mica schists and gneisses are so closely associated that the relations between the two groups are doubtful. In fact, they seem to grade into each other by imperceptible stages. If they are really distinct, metamorphism may have caused the seeming coalescence. The origin of these rocks has not been ascertained.

At two localities rocks which seem to be clearly of sedimentary origin have been found intimately mingled and infolded among the other schists of the series. Whether they were originally interbedded with the lava flows or are of later age and have been folded down into them, or whether they bear some still different relation to them, are unanswered questions.

Prospect pits 2 miles northwest of McLaughlin's ranch disclose white quartz-muscovite schist in which certain bands are very rich in fibrous tremolite or wollastonite. These rocks have been so intensely metamorphosed that no trace of original bedding or fragmental structure remains, and only their mineral composition now suggests that they were once sediments. Quartz-muscovite schists can be derived only from rocks that are very rich in silica and low in the ferromagnesian components, and wollastonite implies an abundance of lime without iron. Schists of this sort are readily produced in the extreme metamorphism of quartzite or of siliceous limestone.

At two other places there are rocks which seem to have been derived from sediments; they have wholly recrystallized but are not schistose.

Near the state line, 1½ miles west of Bald Mountain, a purple rock resembling quartzite forms part of a twisted schistose mass intruded by granite gneiss on the north and dioritic gneiss on the south. Microscopic examination reveals an interlocking mosaic of quartz crystals with scattered granules of epidote and oxides of iron. The iron oxides are present in very small quantities but serve to give the rock its color. Here, again, the mineral composition of the rock strongly suggests that it has been derived from a quartzite, but the complete recrystallization of its components has obliterated all hint of its primitive structure and hence the surmise as to its origin falls short of being verified.

Another rock thought to be a recrystallized quartzite appears as an inclusion in the granite north by east of Boyce's ranch. Except that it is green and somewhat finer grained, it does not differ greatly from the rock just described. With it, however, is a rock whose weathered surfaces are smooth but undulating, as in many dense limestones. This is dull greenish in color and fractures like a hard limestone or argillite. The microscope shows, however, no trace of carbonates, but rather a minutely crystalline mass of quartz resembling flint in its uniform texture and in its kaleidoscopic aspect between crossed nicols. There are no phenocrysts or textural variations of any sort. During metamorphism under deep-seated conditions limestones are liable to silicification and may become changed to masses of chert devoid of carbonates. The rock here considered may well have had this origin, and yet, again, the evidence is not conclusive.

Horse Mountain and northern areas.—In the northern part of the Sherman quadrangle three fair-sized outcrops and a number of small slivers of the schists are enveloped by the younger igneous rocks. As elsewhere, they comprise a mixture of various metamorphic rocks, ranging from massive to slaty in structure and from acidic to basic in composition. Hornblendic schists found among them are not essentially unlike those in other parts of the district, but the other varieties require additional mention.

At Horse Mountain the prevalent rocks are largely greenish and gray siliceous rocks of uncertain origin. Layers of a black variety are intercalated with the lighter kinds and all are distinctly bedded, as if derived from sediments. Their mineral character, however, is peculiar and does not necessarily bear out that supposition. Being very hard and resistant, they are slightly salient in the topography. Horse Mountain and lesser hills in the vicinity owe their elevation to rocks of this series.

When examined microscopically the gray rocks prove to consist of lime feldspar, quartz, and pyroxene, with an unknown colorless mineral. All the minerals appear as rounded interlocking grains, or some are embedded in larger crystals, poikilitically. The black varieties are merely richer in pyroxene and lacking in quartz.

In composition and in structure these peculiar rocks do not resemble any common igneous rocks. Not improbably they were once sediments which have been so highly metamorphosed that they have completely recrystallized, without the production of schistose structure.

Certain other varieties belonging to this same series but found southwest of Horse Mountain consist entirely of interlocking grains of quartz. They are thought to represent highly metamorphosed quartzites.

The ancient schists exposed west of Raggedtop Mountain are very different from those described above. The prevalent rock is a dark coarse-grained biotite schist, varying locally to a banded mica gneiss. Being a soft rock it weathers into subdued forms and fresh outcrops are scarce. The granites and anorthosite are clearly intruded into it. This dark schist is apparently older than even the granite gneiss of Raggedtop Mountain, for the gneiss contains fragmentary inclusions of a black schist like it, and these xenoliths are most abundant near the gneiss-schist contact. This schist is therefore thought to be equivalent in age to the other schists, although it has not been found directly in contact with them.

Structure.—All of the rocks in this series have been intensely folded and metamorphosed, so that it is usually not possible to detect definite structures or, when they are detected, to trace them for any considerable distance. In some places, however, the stratification of the ancient lava flows may be discerned; in others it is clear that the rocks occur as dikes.

Where identified the beds are always highly inclined and are no doubt complexly folded in a large way, just as they are crumpled in detail. The dominating structures, however, are not due to the folding but to the production of schistosity. This is expressed in color banding and cleavage. Although local variations are numerous the general trend of the schistosity is east by north, averaging about N. 70° E.

GRANITE GNEISS.

General character and distribution.—The next series of rocks is clearly younger than the ancient schists and contorted gneisses. It consists of granitic gneisses which have been on the average less altered than the schists and which are therefore more confidently interpreted. That they are mildly metamorphosed granites is obvious from their mineral composition and their field relations, noted later.

The granite gneisses have a distribution similar to that of the ancient schists and are closely associated with them. In addition, an isolated patch of the gneiss forms the northwestern part of the Sherman Mountains east of Laramie. Two distinct types of rocks, which are of slightly different age, are comprised in this series, and each of them has certain variations of its own. The older and more widely exposed is the gneiss that outcrops prominently in the valley of Dale Creek near the southern border of the Sherman quadrangle. The younger variety forms the summit and much of the slopes of Jelm Mountain, in the southwestern part of the Laramie quadrangle.

Gneiss of Dale Creek.—This rock is a fairly coarse grained biotitic gneiss in which the parallel streaking is everywhere distinct, although not so pronounced as to obscure the granitic aspect of the rock. It rarely shows definite bands or contorted laminæ. Along Dale Creek and again east of Cheyenne Pass it is reddish and decidedly coarse in texture. North of Leslie, on the other hand, and north and south of Hecla the gneiss is medium grained and of a clear gray color. These two varieties were not found in contact with each other, and it is not known whether they are of different ages or are merely phases of a single formation. In the Sherman Mountains both types are found with many other varieties from finely lined lavender-colored gneisses to unusually coarse grained augen gneiss.

The gneiss seems to be more resistant to weathering than the granites, so it stands out in the form of hills, such as Pole and Raggedtop mountains. The banding and other structures are everywhere nearly vertical, and weathering along bands of different composition tends to produce sharp reefs, pinnacles, and crags. Raggedtop Mountain derives its name from features of this kind. The craggy appearance of the gneiss outcrops distinguishes them from exposures of the Sherman granite, which normally have massive rounded aspects.

The coarse red phase of the gneiss contains pink alkali feldspars with quartz and biotite. The microscope shows clearly that in its deformation the rock has been mashed and partly recrystallized. It has a banded structure, certain bands being composed of cloudy broken feldspars and strained quartzes, which are more or less granulated along their edges, while others parallel to them are composed of clear quartz, microcline, and biotite. The former bands doubtless represent the original material of the rock; the latter are thought to be secondary, in the sense that they have recrystallized in laminated arrangement. It is this structure which gives the streaked appearance to the specimens. Some of the older feldspars are half an inch to an inch in diameter and lie in eyelike spots past which the micaceous bands swerve like lines of flow. These not improbably are phenocrysts inherited from the granite of which the gneiss was made.

The gray phase of the gneiss is somewhat finer grained and rather more schistose in structure. Its feldspars are white albite and orthoclase. Locally hornblende and epidote are mingled among the seams of black mica.

From the present composition and texture of the gneiss along Dale Creek, it is clear that it was once a granite and is now moderately metamorphosed. Originally the reddish phase must have resembled the coarse-grained pink Sherman granite by which it is now intruded. Were it not, indeed, for the occurrence of many clear contacts which prove that these two rocks are of vastly different ages it might be thought that the gneiss was merely a locally deformed phase of the Sherman granite.

The contact between the gneiss and the schists is highly irregular in detail. Dikes and veinlets of the gneiss reach out into the schists, and xenoliths or angular fragments of the schists are found enveloped by the gneiss. The intrusions issuing from the gneiss break indiscriminately through hornblendic schists, rhyolite schists, gray mica schists, and other rocks. During the metamorphic episode which produced the banding of the gneiss these dikes were twisted, broken, and made schistose.

Gneiss of Jelm Mountain.—Exposures of this gneiss occur not only in Jelm Mountain, but in the hills south of it. Again, in the southern part of the Sherman quadrangle a granite gneiss that is believed to be identical with the gneiss of Jelm Mountain is an important component of the Twin Mountains and is exposed at several places in their immediate vicinity. As a fairly resistant rock, the gneiss of Jelm Mountain stands out in hills and ridges. Jelm Mountain and the Twin Mountains are ribbed with it. Because of its uniformity, however, the outcrops of the gneiss are not craggy nor serrate but resemble those of a massive granite of firm construction.

The gneiss of Jelm Mountain is different from the gneiss of Dale Creek in appearance and in lithologic features. It is a fine to medium grained reddish gneiss, ordinarily deficient in the darker minerals. It is therefore of more acidic composition than the gneiss of Dale Creek. The gneissic structure is a little less distinct in this variety than in the other. In fact, the rock might be mistaken for an ordinary granite if the outcrop happened to be obscure or deeply weathered. Under more favorable conditions, however, the streaky appearance due to parallel arrangement of the minerals may be clearly seen. The gneiss of Jelm Mountain appears to be rather more uniform in texture and composition than the variety occurring along Dale Creek. Locally it contains a fair proportion of biotite; elsewhere even the muscovite is scarce. But its color is relatively constant, and coarse porphyritic phases are lacking.

Microscopic study of the rock from Jelm Mountain shows that it consists of quartz and alkali feldspar (most of which has the structure of microcline), with muscovite, a little biotite, and iron oxides. The micas are roughly parallel and are associated with partly recrystallized seams of quartz and feldspar. The rock appears to have been severely mashed and largely recrystallized, but the paucity of the mica and other dark silicates which favor ready cleavage leaves it less schistose than the other gneisses.

At Twin Mountains the hard pink gneiss is similar, except that it contains iron oxides with very little mica. A variety occurring near McPhee ranch, however, is speckled with hornblende and biotite.

At Jelm Mountain the gneiss has been intruded into the dark schists of the older system, leaving a very irregular contact between the two. Near the junction of the two rocks pieces of schist are embedded in the gneiss and dikes of the gneiss invade the schists. Secondary minerals, such as garnet, are common in the schists for some distance away from the contact.

In the Twin Mountain region the rock which is correlated with the gneiss of Jelm Mountain occurs as elongate intrusions in the schistose series and also as dikes in the gneiss along Dale Creek, where the two have been found in contact. This establishes the fact that the one is somewhat younger than the other, but as both have been metamorphosed to a similar degree and bear the same relation to the older schists on the one hand and to the basic intrusives, porphyries, and granites on the other, it is safe to believe that they belong to the same general division of time.

Gneissic dikes.—Both of these gneisses, as well as the adjacent schists, are cut by small dikes of fine-grained granite gneiss. In the gneiss along Dale Creek these dikes are gray in color and biotitic; in the gneiss of Jelm Mountain they are dense, red gneissic granites containing a small amount of muscovite. From the striking similarity of the dikes in each place to the gneisses which they invade it is thought probable that they are genetically connected with those rocks, or, in other words, that both the massive gneiss and the dikes were made from the same body of magma, the dikes having been intruded into the gneiss during the later stages of its cooling and solidification.

Large dikes or masses of pegmatite that lie within the schist and gneiss of Jelm Mountain are thought to have been formed by emanations from the gneiss during the later stages of its intrusion. This view is favored by the facts that the dikes are very numerous near the main body of gneiss and that the pegmatite consists of the same minerals as the gneiss—quartz, pink feldspar, and muscovite. The mica is especially abundant and occurs in flakes so large that an attempt has been made to develop mica mines from some of the pegmatite deposits.

OLDER BASIC INTRUSIVES.

General character and distribution.—Under this head are grouped a number of dark igneous rocks which outcrop in small but widely scattered areas. The largest exposures are south of Tie Siding, near Bald Mountain, and at the extreme north edge of the Sherman quadrangle. They have little in common except the facts that they are dark colored and mostly basic in composition and that they belong to the same general position in the time scale of the district. They comprise syenites, gabbros, diorites, granodiorites, and gabbro gneiss. The rocks are partly of coarse-grained texture and partly dense or porphyritic. Some of them are essentially unaltered; others have been katamorphically changed without the loss of original structures; still others are distinctly gneissic.

No definite topographic forms mark the outcrops of the basic intrusives. Near the south edge of the Sherman quadrangle they stand out as dark hills partly mantled with coarse talus. In Ring Mountain, in the southwestern portion of the Laramie quadrangle, they form small, bare knobs projecting from the granite gneiss. Near Tie Siding and in most other places they have weathered flush with the surrounding rocks. Even here the brownish loam which they yield on decay is notably unlike the coarse gravelly soil of the Sherman granite.

Age and relations.—As a group, the older basic intrusives are intermediate in age among the pre-Cambrian formations. They are intruded not only into the ancient schists but also into the granite gneiss of Dale Creek. On the other hand, the great mass of Sherman granite surrounds them and sends many dikes into them. Even the anorthosite near Leslie, which is itself older than the granite, irrupts the gabbro gneiss along the northern border of the Sherman quadrangle. The basic intrusive rocks are therefore younger than the granite gneisses and older than the granites and anorthosites.

The various intrusives in the group, however, may differ considerably in age. It is probable that the gneissic varieties on the north and south edges of the Sherman quadrangle are older than the nearly unaltered gabbros and syenites of other localities. It is possible that some intrusions distinctly older than even the granite gneisses have been included here because of lithologic resemblances.

Description.—The outcrop south of Tie Siding displays syenites, diorites, and a variety of other rocks, some apparently segregations and others intrusions, but all more or less related in mineral constitution.

The prevalent phase is a pink and black diorite of medium texture. The minerals shown by the microscope are sodic feldspar (chiefly oligoclase) and green hornblende. Locally the rock is porphyritic, having large crystals of feldspar sparsely distributed through it. Some darker varieties are rich in biotite, in addition to the hornblende; others grade into quartz diorites by increase in quartz, or into monzonites and syenites by the prevalence of orthoclase feldspar. Iron oxides are abundant in the form of grains and dustlike particles. At certain points the feldspar has been wholly altered to epidote and quartz, and the rock has therefore a bright-green color.

The gabbros have been found at Bald Mountain and near Key's ranch in the Sherman quadrangle. They are coarse-grained blackish rocks, with poikilitic or ophitic textures. They appear to have consisted originally of lime feldspar and augite, with or without hornblende. But they have been katamorphically altered either partly or entirely, without modifying their original structures. In some the original pyroxene is replaced by fibrous green uralite; in others even the lime feldspars have been altered to alkali feldspar and epidote or zoisite. The uralite usually preserves the stubby, short prism forms possessed by the older pyroxene.

A small intrusion in the schistose rocks of the Twin Mountains consists of diorite. It is a speckled gray rock of rather fine texture, in which long needles of hornblende are readily seen. Microscopic examination reveals soda-lime feldspar and hornblende, with a small amount of biotite, quartz, and potash feldspars. It thus verges toward quartz monzonite. This rock has suffered no alterations worthy of mention.

Related rocks, some of which are really quartz diorites, occur as large inclusions in the Sherman granite, especially east of the Sherman Mountains. They are fine-grained, sparsely porphyritic rocks consisting mainly of sodic plagioclase, hornblende, and biotite, but with notable amounts of quartz and some microcline.

Dioritic gneiss, assigned to this general group but perhaps older, appears at the extreme southern edge of the Sherman quadrangle. The intrusive character of this gneiss is sufficiently proved by the contact features of the stock. It invades ancient mica schists and has metamorphosed them peripherally into spotted schists. The rocks are black and white, distinctly streaked, and probably have wholly recrystallized under anamorphic conditions. The chief minerals, lime-soda feldspar and green hornblende, are arranged in parallel bands, yet the individual crystals are not strained.

At the northern edge of the same quadrangle the largest exposure is that of a black-gray gabbro gneiss. It consists of lime-soda feldspar and augite, with an unusual abundance of magnetite in the form of irregular bodies scattered through the mass. Nodules of pure magnetite the size of walnuts may be found in the brown residual soil above the gneiss.

GRANITE PORPHYRY.

General character and distribution.—The rocks belonging to this group are confined almost entirely to the region south of the railroad in the Sherman quadrangle. At Granite Canyon, however, they extend northward across the railroad and appear also in a small patch farther north, near Arp's ranch.

Outcrops of the granite porphyry have the irregular form of intrusions where they invade the older rocks and are equally irregular where embedded as more or less isolated bodies in the prevailing Sherman granite. Although several types of granite porphyries occur in the region, only one is either widely exposed or well known as regards its relations and age. This is the gray or brownish granite porphyry, which is best exposed near Granite Canyon and southeast of Sherman. It has the composition of hornblende granite, the constituents appearing both in the form of a dense groundmass and as small phenocrysts embedded in the groundmass.

Relations and age.—The granite porphyries are intruded into the ancient schists and gneisses from Granite Canyon southwestward, and also into the gneiss of Dale Creek south of Sherman, where they are cut off and locally surrounded by the great mass of Sherman granite. They are therefore distinctly older than the granite but younger than the schists and gneisses. Their age with reference to the older basic intrusives and to the anorthosite is still in doubt, for they have not been found in contact with either. In this connection it is significant, however, that some of the dioritic rocks have been notably metamorphosed, that the granite porphyries show some evidence of deformative alteration, but that the other basic intrusives and the anorthosite have not been perceptibly deformed. These conditions indicate that the granite porphyries are younger than some of the basic intrusive rocks, although older than the syenites, the unaltered gabbros, and the anorthosite.

Description.—The typical granite porphyry is a dark-gray rock of uniform character, locally tinged with purple. The weathered outcrops have a rusty brown color, and even freshly broken surfaces near the outside are brownish gray. The grayish ground color is varied by the little spots of green hornblende, quartz, and pink feldspar which represent the phenocrysts. Of these the feldspars are the largest, averaging about one-eighth of an inch in diameter.

Microscopically the rock consists of a finely granular matrix set with phenocrysts. The phenocrysts comprise orthoclase, quartz, and hornblende, and the groundmass is composed of the same minerals in minute grains. Shreds of biotite are found in some specimens. The phenocrysts are not idiomorphic but rounded. Strain shadows, fractures, and microcline grating indicate that the rock has been slightly deformed, but not so far as to produce recrystallization and gneissic structure.

Near the borders of intrusive masses, especially in the small dikes that emanate from them, interesting variations of the porphyry are found. Usually the texture of these varieties is considerably coarser than that of the others, the feldspar crystals being more than a quarter of an inch in diameter and decidedly idiomorphic. In some places these coarser dikes cut the porphyry itself, but as they have also been traced into the main body of the intrusion by a perfect gradation, it is evident that they were really derived from the same magma.

Where the contact is a breccia zone other variations may be seen, the ordinary porphyry blending by loss of phenocrysts into pink microgranite and by increase of epidote into green felsite. The inclusions of the older rocks are locally changed to knotted schists by the growth of large hornblende crystals under the influence of the intrusion.

A different quartz porphyry, probably unrelated to the one described above, forms small intrusions on the east side of the Twin Mountains and is found among the inclusions in the Sherman granite. It is bluish gray and contains very large crystals of white orthoclase and quartz embedded in a matrix of quartz, feldspar, and biotite. Its relationships are not known.

ANORTHOSITE.

General character and distribution.—The anorthosite is exposed only in the northern part of the Sherman quadrangle. There are two broad outcrops, each occupying several square miles, and adjacent to these are smaller patches. Owing to the fact that the rock contains little but gray feldspar, its prevailing color is a clear dull gray. Locally it has a speckled appearance, due to the presence of more or less black hornblende. As it resists weathering a little better than the coarse Sherman granite, it usually forms somewhat higher hills than that rock. These hills, however, are unlike those in the gneiss and schist areas, in that their outlines are softened and subdued rather than rugged.

Relations and age.—The anorthosite is intruded into the siliceous metamorphic series near Horse Mountain, into the dark mica schist near Brown's ranch, and into the granite gneiss north of Leslie. It is therefore distinctly younger than either of the two oldest series of rocks. On the northern edge of the district it also invades the dark gabbro gneiss which extends into this quadrangle from the north. It appears, therefore, that the anorthosite is younger than at least some of the older basic intrusives. It may be younger than all of them. On the other hand, the anorthosite is bounded along an irregular line by the Sherman granite, which is intruded into it. Many dikes of various sizes issue from the granite and traverse the anorthosite. In the vicinity of Leslie, and for several miles around, these dikes are particularly numerous and conspicuous. Small bodies of anorthosite are also embedded in the granite on the outskirts of the larger outcrops. It is clear, then, that the anorthosite is older than the granite. Its age with reference to the granite porphyries has not, however, been ascertained. Both of these formations stand in the same relation to the older and the younger series, and so, for the present, it may be said that they are not far apart in age.

Description.—There are so many variations in the anorthosite that a single description does not apply equally well to all of its varieties. Generally the rock is clear gray in color, has a medium granitoid texture, and consists of feldspar with a small amount of black-green hornblende. Its texture varies, however, from rather fine grained to very coarse. At the extreme northern edge of the district the rock is locally composed of iridescent bluish feldspar crystals generally ranging from 2 to 4 inches in length, although single crystals more than 6 inches long are not rare. In some varieties the texture is granular; in others there are large feldspar phenocrysts; and in still others small idiomorphic feldspars are embedded in a matrix of hornblende, giving the rock an ophitic texture. In one extreme of the anorthosite no minerals other than the feldspar appear, but from this variety there are all gradations to a typical epidiorite in which hornblende is abundant. The basic phase is best seen near Leslie and at places farther south; the plain anorthosite is prevalent west of the gabbro gneiss outcrop, farther north. As a rule the anorthosite shows no evidence of deformative metamorphism, although traces of gneissic structure may be observed locally near its contact with the Sherman granite, where the influence of the intrusion has been strong. This type should not to be confused with varieties that exhibit a parallel arrangement of the feldspars, due apparently to original flow structure.

Microscopic study of the pure anorthosite reveals lime-soda feldspar (labradorite) with traces of green hornblende. The texture is coarsely granitoid. Little evidence of alteration is to be seen. A specimen from the Strong copper mine carries about 10 per cent of hornblende with bits of metallic sulphides and biotite. In the ophitic variety hornblende is still more prominent. It occupies the spaces between the feldspar prisms and thus cements them together. The hornblende incloses irregular bodies of diallage. There is reason to believe that this is the original ferromagnesian mineral of the rock and that the hornblende has been produced from it by slow molecular changes.

SHERMAN GRANITE.

General character and distribution.—The granites of the two quadrangles are the most widespread of the pre-Cambrian formations. They occupy not only the larger part of the Sherman pre-Cambrian belt, but all of Sheep Mountain and practically all of Boulder Ridge. The rocks may be readily separated into two groups—(1) coarse-grained massive granite occurring in one or more bodies of vast size; (2) fine-grained and locally porphyritic granites, occurring usually in dikes or small stocks, together with dikes of graphic granite and coarse pegmatite. The first variety has been named the Sherman granite. The dike granites, which on the geologic sheets are mapped as Sherman granite, branch out from this coarser granite or actually cross it as later intrusions. It is believed, however, that all these rocks are referable to a single parent magma and to one general episode of intrusion.

Relations and age.—As has already been indicated the granites are almost the youngest of the pre-Cambrian rocks. In the northern and southern parts of the Sherman quadrangle they are intruded into the ancient schists, granite gneiss, older basic intrusive rocks, and granite porphyries. South and east of Leslie they invade the anorthosite. They are thus younger than all these formations. The unaltered character of the granites would alone serve to indicate that they are among the younger rocks of the district, as the oldest formations are distinctly metamorphosed and some of the intermediate members are locally altered. The granites are cut by only the younger basic dikes—the most recent intrusive rocks in the district.

Sherman batholith.—The coarse Sherman granite occurs in the form of one or more large batholiths and in subsidiary intrusions. There is no direct evidence of the existence of more than one of these great masses, but the covering of later sedimentary rocks makes it impossible to trace the granite from one outcrop to another. It is clear, however, that the great exposure in the Sherman uplift is a single continuous body. The depth of the granite mass is unknown, except that it exceeds 1000 feet, but there is considerable evidence to show that it underlies many of the patches of gneiss and schist that interrupt its outcrops on the surface. The contact between the batholith and these older rocks is at some places nearly horizontal, at others moderately inclined, and elsewhere essentially vertical. The shape suggested is that of a very flat dome with minor irregularities; but it must be admitted that the mass is not sufficiently laid bare in this region to give a clear idea of its contour.

Description.—Normally the Sherman granite is a very coarse grained rock, composed chiefly of pink feldspars, glassy quartz, and black hornblende and mica. A spotted pink aspect is the result of this combination.

The microscope shows that the feldspars are all alkaline, largely orthoclase and microcline, with some oligoclase. The shades of red are caused by varying amounts of hematite dust included in the feldspars. The hornblende predominates over the biotite, but both are essential. As a rule the granite shows no evidence of deformation, but here and there strain shadows and sheared feldspars indicate that the rock has been slightly affected by subsequent compression.

Locally the granite shows considerable variation in texture, color, and composition. One of the commonest phases is coarsely porphyritic, the feldspar standing out as more or less perfect crystals 1 to 2 inches in length. The granite of Sheep Mountain is finer grained by half than the typical Sherman rock, but otherwise the two are similar. By a change in the feldspar from white to pink, certain varieties become pale gray; in other varieties the feldspars are deep red, thus giving the rock a much darker appearance than is common. Where the Union Pacific Railroad crosses Dale Creek, and locally on the west slope of Boulder Ridge, the granite is rich in epidote, which, together with the red feldspar, imparts a mottled red and green color. Still another variety, common southwest of Twin Peaks, contains only feldspar, quartz, and magnetite, the last playing the part of hornblende.

Although hard in its unaltered condition the Sherman granite disintegrates readily under the influence of descending surface waters and produces a coarse gravelly soil, which is characteristic of the region it occupies. In excavations at Buford the granite has been found to be decayed to a depth of 40 to 50 feet, the ferromagnesian minerals having been decomposed, leaving the quartz and feldspar intact. Where thus deeply weathered, the outcrops of granite are smoothly rounded and free from visible ledges. (See fig. 7, illustration sheet.) In hills and canyon walls, however, where the rock is still firm, it weathers along widely spaced joints and gives rise to heaps of rounded bowlders, some of which are of huge size.

At the contact between the granites and the older rocks there are numerous special features that require mention. At some points this contact is sharp, a continuous mass of gneiss on the one hand being separated by a definite line from a continuous mass of granite on the other. Elsewhere, notably on Dale Creek just north of the state boundary, the contact is not a line but a broad zone of breccia, which consists of fragments of the older rocks cemented by the granite. From the outer side of this breccia dikes of granite, varying considerably in texture and composition, reach far into the older rocks. On the inner or granite side of the breccia the number of angular fragments of the older rocks decreases somewhat gradually, until finally they are merely scattered xenoliths embedded in the continuous granite mass.

Whether the contact is a definite line or an indefinite zone it is remarkable that the country rock is as a rule not highly metamorphosed. In the vicinity of many batholiths of granite elsewhere the adjacent rocks have been altered through a radius of 1 to 5 miles, or even more, but here the alteration is rarely noticeable more than a few rods from the contact and at some places it is not apparent an inch away from the dividing line. At many points along the contact between the granite and the granite gneiss or the granite porphyry no evidence of thermal alteration is visible without the aid of the microscope. On the other hand, the granite itself takes on a gneissic structure at certain points very close to the confining roof, as if it had been mashed or dragged during the process of solidification.

Granite dikes and veins.—In addition to the many dikes which emanate from the granite contact and cross the older rocks, there are others which cut the Sherman granite itself and must therefore be younger in age. These comprise granite porphyry, fine-grained granite and syenite, graphic granite, coarse pegmatite, and quartz veins. The first two correspond exactly with observed offshoots from the Sherman granite, and it can scarcely be doubted that they were produced from the same magma. Pegmatite also has been traced into a porphyry dike, which in turn arose from the granite. It is probable that the veins of pegmatite and of quartz have been made by hot solutions which exuded from the granite as it slowly cooled.

The dike granites are as varied microscopically as in external appearance. Only a few of the principal types can be mentioned here.

A medium-grained gray granite with a few large feldspar phenocrysts forms a small stock at Greentop Mountain and many large dikes in the central and northern parts of the Sherman quadrangle. It consists largely of quartz, potash feldspars, and biotite, but sodic plagioclase is present as phenocrysts and in the groundmass. Hornblende is scarce.

The prevailing dikes in the Sherman Mountains, near Leslie, and in fact generally throughout the district, are fine-grained pink to gray granodiorites. Many of them are more or less porphyritic. The chief minerals are potash and sodic feldspars with quartz and biotite. The biotite tends to disappear in the finer-grained varieties, giving binary granites. These granodiorites grade into ordinary granites by a decrease in the proportion of plagioclase, or into monzonites and syenites by deficiency of quartz.

Small dikes of graphic granite and pegmatite traverse the Sherman granite and all the older rocks in the district. Milky quartz alone, or quartz and pink feldspar, in coarse crystals, make up the pegmatites, which not uncommonly carry also biotite. Pseudomorphs of chlorite after biotite occur in pegmatite near Tie Siding.

Almost all of these younger dikes are more resistant to weathering than the coarse Sherman granite. They therefore have a tendency to stand out as hills and ridges. In many places this contrast of relief is slight, but in the Sherman Mountains very large dikes of fine-grained granite, some of them 600 to 800 feet thick and several miles long, uphold all of the higher peaks. Greentop Mountain, in the north, owes its elevation to a small stock of the coarse porphyritic granite. The granite dikes are most abundant in the vicinity of Leslie and in the region extending from that place northeastward. Many of them are present in the central portion of the quadrangle or in the area extending thence southward to the state boundary. In Boulder Ridge they are fairly abundant, but in Sheep and Jelm mountains they are decidedly less common.

BASIC DIKES.

General character and distribution.—The smallest and least important of the several pre-Cambrian formations comprises small dioritic and diabasic dikes, which traverse all the other rocks indiscriminately. The largest of them is not more than 30 feet thick and many measure only a few feet. For this reason they are not shown on the geologic maps. These trap dikes are most abundant near Tie Siding and in areas south and southwest of that place. A very few are found farther east and some occur in the Sherman Mountains. They are rare in the northern half of the Sherman quadrangle and the southwestern part of the Laramie quadrangle. Although on the average they weather somewhat less rapidly than the granite they seldom express themselves definitely in the topography. Here and there they protrude slightly from the weathered surface, forming greenish ledges, but nothing more.

Age and relations.—The fact that the basic dikes cut the Sherman granite and all older granites marks them as the youngest eruptive rocks of the district. They have not been seen in actual contact with the granitic dikes, but as these dikes appear to be merely phases of the greater mass of granite it is fair to suppose that the diabases are still younger. Since they are cut off by the Carboniferous sedimentary formations they are, however, members of the great pre-Carboniferous complex.

Description.—The rocks are chiefly dense greenish-black varieties in which few of the minerals can be seen. They fracture irregularly and on weathered surfaces are greenish gray or rusty brown.

Under the microscope the rocks reveal evidence of extensive alteration, which has obscured their original character. Lime-soda feldspar and greenish decomposition products, probably derived from pyroxene, are their essential constituents, and magnetite, pyrite, and apatite usually appear in small quantity. The texture is in places ophitic and ranges from densely aphanitic to finely granitoid. Phenocrysts of feldspar are sparsely distributed through many of the varieties.

The basic dikes are all too small to have produced marked contact alterations in the rocks through which they were intruded, but locally they seem to have indurated the country rock for a few feet on either side.

POST-CAMBRIAN SEDIMENTARY ROCKS.

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

CARBONIFEROUS SYSTEM.

In northern Wyoming the pre-Cambrian granites, schists, and other rocks are overlain by nearly 1000 feet of Deadwood sandstone (Middle Cambrian), upon which lies 200 to 300 feet of Bighorn limestone (Ordovician) and about 1000 feet of Madison limestone (Mississippian). These deposits grow thinner toward the southeast and finally disappear in south-central Wyoming, so that in the Laramie-Sherman region the Casper formation, of Pennsylvanian age, lies directly on the pre-Cambrian rocks. The rocks of the Casper formation are limestones and sandstones somewhat like those of the corresponding Amsden and Tensleep formations of central and northern Wyoming. South of the latitude of Laramie, however, the sandstone predominates, finally to the exclusion of the limestones, and much of it is red in color. Near Laramie the Casper formation is overlain by a deposit of red shale, named the Satanka shale, on which rests the thin Forelle limestone.

CASPER FORMATION.

General character and outcrop.—The Casper formation, the lowest division of the sedimentary rocks in this region, consists of limestones, dolomites, and sandstones of various colors. It outcrops along both sides of the Laramie Mountains, and appears also in the vicinity of Ring and Jelm mountains, in the southwest corner of the Laramie quadrangle. In their southern and especially in their southwestern extension these sediments gradually pass into red beds, which consist largely of coarse red sandstone. The Casper formation constitutes the crest and west slope of the Laramie Mountains, and as its dip is low its outcrop is wide. The southern end of this area lies about half a mile south of the Colorado boundary, in the narrow syncline between Boulder Ridge and the Laramie Mountains. Its outcrop extends around the point of the Boulder Ridge anticline and reappears in the uplifts adjoining Ring and Jelm mountains. Along the east side of the Laramie Mountains, where the dips are steep, the Casper formation constitutes a sharp but narrow ridge that is interrupted in places by stream gaps and by slopes containing overlapping Tertiary deposits. In Mesa Mountain, where the formation lies in a shallow syncline, its zone of outcrop widens to about 2 miles. Its width also increases in the region south of Granite Canyon, where the angle of dip decreases. The formation is remarkably uniform in character on opposite sides of the Laramie Mountains. It is named from typical exposures in Casper Mountain, in central Wyoming.

Thickness.—In thickness the Casper formation has a considerable range. The maximum thickness observed was in Gilmore Canyon southeast of Laramie, where a measurement gave 1007 feet. The amount diminishes toward the south and southwest, so that on Sand Creek the formation is but little more than 500 feet thick. On the northwest slope of Red Mountain it is about 600 feet thick. On the east side of the Laramie Mountains its thickness near the State boundary was found to be 797 feet. In the isolated ridge northeast of Granite Canyon station a section of the greater part of the formation measured 795 feet. A section measured by Mr. Blackwelder halfway between the forks of Lodgepole Creek gave 934 feet. On Horse Creek the formation is only about 500 feet thick, but its thickness increases to 750 feet on the North Fork of Horse Creek.

Local features on the west side of Laramie Mountains.—The principal features of the Casper formation in the vicinity of Laramie are illustrated in a well-exposed section in Gilmore Canyon, as follows:

Section of Forelle, Satanka, and Casper formations in Gilmore Canyon, Wyoming.

	Feet.
Forelle limestone (20 feet).	
Satanka shale (red shale, some red sandstone, 232 feet).	
Casper formation:	
Sandstone	2
Red shale with some thin beds of white and red sandstone	120
Red to buff sandstone	65
Limestone (fossiliferous)	8
Upper "monument" sandstone	45
Hard limestone, buff	$2\frac{1}{2}$
Lower "monument" sandstone, red	78
Massive lumpy limestone, in middle of hill 1 mile west of Colores	20
Reddish soil; rocks concealed	33
Red sandstone	92
Thick-bedded limestone containing *Spirifer cameratus*	24
Salmon-red fine-grained sandstone	120
Purple limestone	4
Concealed; shale (?)	110
Limestone with crinoid stems	5
Concealed; shale (?)	45
Purplish sandy limestone	15
Shale (?)	50
Sandy purple thin slabby limestone	3
Shale (?)	15
Slabby purplish sandy limestone	15
Massive shelly cross-bedded purple sandy limestone	25
Concealed; probably red shales and sandstones	90
Purple sandy oolitic limestone	1
Massive red arkose and conglomerate ($\frac{1}{4}$-inch pebbles)	20
Granite.	
	$1007\frac{1}{2}$

This section exhibits twelve beds of limestone, from 1 to 25 feet thick, 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 generally crystalline, in many places sandy, and range from purple to white in color. The purple-limestone members near the base of the formation extend for many miles along the Laramie Mountains. A thick bed of limestone in the lower middle portion of the formation is especially conspicuous in Cheyenne Canyon, where it lies on bright-red sandstone which is in turn underlain by about 100 feet of gray sandstones. In slopes 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 rises out of the red-shale valley and constitutes the lower mountain slopes. East of Laramie this sandstone is overlain by a 6-foot bed of limestone, which is extensively quarried. This limestone 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.

Although limestones predominate about Laramie and north of that place, red shale and arkosic sandstone are the prevailing rocks in the vicinity of Tie Siding and in areas farther west. The limestones do not disappear, however, but most of them persist as thin beds as far as the Boulder Ridge fault. The limestones at many places form cliffs and ridges of considerable height. In the Red Butte region and southwest of it, about 250 feet below the top of the formation, there is a sandstone member, nearly 200 feet thick, which is 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. Typical forms of these monuments are shown in figures 8 and 9 of the illustration sheet.

The thinning of the formation toward the southwest is illustrated by the following section, in which the thickness is less than half that seen in Gilmore Canyon and the limestone members diminish both in number and thickness.

Partial section of Casper and overlying formations near Pulpit Rock, on Sand Creek, at Colorado state boundary.

	Feet.	
Chugwater formation:		
Gypsiferous limestone in wavy layers	2	
Red shale with aragonite	100±	
		102±
Forelle limestone:		
Gypsiferous limestone in wavy layers		4
Casper formation:		
Light buff sandstone and shale	100±	
Flaggy to massive light-colored sandstone	30	
Limestone (thins out)	1	
Massive fine-grained red "monument" sandstone	40	
Shale, arkosic sandstone, and conglomerate	40	
Heavy blocky limestone	5	
Sandstone, arkose, and conglomerate	170	
Sandstone	5	
Arkosic sandstones and conglomerates	80	
Limestone	2	
Arkosic sandstones and conglomerates	25	
		498

The section given below is condensed from one published by W. C. Knight, subdivided according to present classification.[a] The lower portion of this section was measured on Sand Creek near Pulpit Rock.

Section of Casper and overlying formations at Red Mountain.

	Feet.	
Chugwater formation:		
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	
		850
Forelle limestone:		
Fossiliferous rock		4
Casper formation:		
Gray sandstone	20	
Red sandstone	15	
Interval; not over	50	
Red sandstone	152	
White to red shaly sandstone	96	
Reddish fine-grained "monument" 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.		$786\frac{1}{3}$

Another section of the Casper formation, measured on the north face of Red Mountain and reaching to the granite at the south face of Ring Mountain, is as follows:

Section of Casper and associated formations on Red Mountain.

	Feet.
Chugwater formation:	
Gypsum (67 feet).	
Forelle limestone:	
Fossiliferous impure limestone (1 foot).	
Casper formation:	
Buff shale and calcareous sandstone	9
Massive light sandstone	50
White sandy shale and a little soft sandstone	55
White, soft massive sandstone	18
White sandy shale	20
Red sandy shales and thin, flaggy red sandstone	90
Pink to white massive sandstone; some arkose	39
Red shale	6
Sandstone	4
Red shale and sandstone and shale; limestone nodules at base	161
Mostly concealed (red shales, sandstones, and arkose)	155
Granite at south base of Ring Mountain.	
	607

In Red Mountain there are only two limestone beds and they are inconstant and impure. The "monument" 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 upon conglomerate consisting of rounded quartz, angular feldspar, and more or less rounded limestone pebbles. East of the creek 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. A similar limestone caps the hill about $1\frac{1}{2}$ miles farther east-northeast 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.

Other sections of the Casper formation are given below.

Partial section of Casper formation in railway cut in southeast corner sec. 1, T. 13 N., R. 73 W., $2\frac{1}{2}$ 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.	

Partial section of Casper formation 600 yards northwest of the preceding section.

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

Partial section of Casper formation at high hill just north of the railroad 1 mile northwest of Colores, Wyo.

	Feet.
Limestone	5
Fine-grained buff to salmon colored "monument" sandstone	97
Limestone forming bench (lumpy limestone of Gilmore Canyon)	13
Terra-cotta sandstone; massive; coarse grained in places	45
Reddish sandy shale and shaly sandstone	40

[a] Jour. Geology, vol. 10, 1902, pp. 418–419.

The long, gentle western declivity of the Laramie Mountains from Laramie to Tie Siding is characterized by extensive smooth grassy surfaces marking the dip slopes of the various limestone and sandstone beds of the Casper formation. These slopes are interrupted here and there by "monuments" of bright-red sandstones. For some distance in the vicinity of Gilmore Canyon the slope is formed by the $2\frac{1}{2}$-foot layer of limestone included in the Gilmore Canyon section, and it is remarkable that a stratum so thin should have controlled erosion to such an extent. The stratum that forms the wide lower slopes a mile north of Colores is the next lower limestone (20 feet thick in the Gilmore Canyon section), which is 13 feet thick in the vicinity of Colores.

Local features on east side of Laramie Mountains.—The Casper formation is much more uniform in character in the eastern front ridge than on the opposite side of the mountains. Limestones predominate, especially to the north, but the formation includes much reddish sandstone. Farther south, in Colorado, it changes to red sandstones, constituting the Fountain formation or "lower Red Beds" (Lyons and Fountain). The following section shows the components of the Casper formation near the Colorado state boundary in the Sherman quadrangle:

Section of Casper formation along Colorado-Wyoming boundary in secs. 23 and 24, T. 12 N., R. 70 W.

	Feet.
Flaggy buff dolomite, underlying Chugwater red sandstone and shale	8
Blocky limestone	4
Red shaly sandstone	11
Alternating shaly limestone and clay	11
Massive pink dolomite; shows bedding when weathered	35
Salmon-colored sandstone	5
Limestone	2
Red sandstone and shale	53
Limestone	10
Red shale (?)	10
Limestone	25
Red sandstone	15
Massive limestone	10
Concealed	110
Buff to blue limestone	35
Red "monument" sandstone	80
Limestone	10
Buff to red "monument" sandstone	70
Bluish to purplish limestone	34
Salmon-colored "monument" sandstone, fine grained	25
Dark-brown coarse-grained sandstone	2
Purplish lumpy limestone	4
Buff arkose conglomerate	6
Dark-brown coarse sandstone	6
Massive slabby purplish limestone	12
Shaly calcareous sandstone and sandy limestone	5
Concealed; shale (?)	15
Purplish sandstone and arkose with limestone cement and lenses of limestone	4
Concealed	180
Granite.	
	797

In the gorge of Duck Creek below Hosack's ranch is exposed the following section. It lacks an unknown but probably small amount of the upper beds of the formation, which are covered by Tertiary strata.

Partial section of Casper formation along Duck Creek, in sec. 36, T. 13 N., R. 70 W.

	Feet.
Massive dolomite	10
Concealed	28
Pink sandstone	4
Concealed	47
Pink sandstone	8
White limestone	10
Concealed	10
Red sandstone	5
Massive limestone	15
Mostly concealed; shale, perhaps with lenses of limestone	95
Massive limestone	15
Concealed	25
Purple limestone	25
Flaggy red sandstone	17
Purple limestone	12
Shale	19
Limestone	25
Shale	3
Limestone	4
Shale	3
Purple limestone	5
Shale	8
Purple limestone	10
Shale (?)	50
Limestone	3
Shale	8
Purple arenaceous limestone	6
Shale (?)	58
Blue to purple limestone	2
Concealed; probably red shale and sandstone, about	180
Gneiss and schist.	
	710

In a section by Arnold Hague in a report of the Fortieth Parallel Survey it is stated that the basal member consists of 100 feet of red sandstone, limy near the top, which is overlain by 400 feet of bluish-gray limestone and 300 feet of limestones, red and sandy below and blue above, with a thin included bed of conglomerate.

The Casper formation is crossed by the Union Pacific Railroad just east of Granite Canyon station, but owing to extensive overlap of Tertiary sediments at that point it is not completely exposed. It appears in the isolated hill a mile northeast of the station in the following section, which probably represents very nearly the entire thickness of the formation:

Partial section of Casper formation 1 mile northeast of Granite Canyon station.

	Feet.
White limestone	10
Red sandstone	40±
Red or purplish limestone	10±
Red sandstone	30±
Red limestone	10
Red sandy shale	30
White dolomitic limestone	10
Red shale, grading into limestone toward top	64
White dolomitic limestone	70
Red sandstone	18
White limestone	4
Red sandstone	19
Red shale	10
Shaly red sandstone	10
Red and white limestone	47
Massive white limestone	65–95
Red shale	45–15
Limestone	43
Shale	17
Limestone with some shale	70
Red massive sandstone	23
Red shaly limestone	85
White massive limestone	12
Red shaly limestone	10
Concealed, probably shale	43
Granite porphyry.	
	795

A complete section of the formation on North Fork of Crow Creek is as follows:

Section of Casper formation at the south end of Mesa Mountain, near Arp's ranch, in sec. 36, T. 15 N., R. 70 W.

	Feet.
Massive white limestone	30
Purple calcareous shale and flaggy limestone	50
Flaggy limestone	10
Arenaceous shaly limestone	10
Purple limestone	40
Heavy-bedded white to gray limestone	40
Red cross-bedded massive sandstone	20
White to gray limestone	1
Red to purple limestone	6
Red sandstone	36
Limestone	2
Hard purple calcareous sandstone	20
Soft red sandstone	20
Light-purple limestone	6
Red limestone	50
White limestone	10
Concealed; débris slope	150
Arkose conglomerate and red sandstone	24
Shale	17
Red flaggy sandstone	15
Particolored shales	10
Calcareous sandstone, conglomeratic base	4
Schist.	
	571

North of Mesa Mountain the proportion of limestone in the Casper formation gradually increases and for some distance the total thickness of the formation decreases to 500 feet or less. On Horse Creek the basal beds are sandy limestone, and near the middle of the section is a 30-foot bed of reddish-brown sandstone. Toward the top the main body of limestone is overlain by a 40-foot bed of reddish-brown soft sandstone, followed by 5 feet of massive white hard limestone and 20 feet of very pale red sandstone. This sandstone is overlain by red sandstone and shale of the lower part of the Chugwater formation.

On the south side of North Fork of Horse Creek the formation consists largely of gray limestone beds separated by several bodies of sandstone, in all about 750 feet thick. At the top there is but little sandstone; at the base there is about 180 feet of sandstone, mostly of reddish color and in part gray. Much of this sandstone is fine grained and slabby but part of it is massive and includes some conglomerate.

Fossils and age.—The limestones and calcareous sandstones of the Casper formation have yielded a few fossils, and sparse faunas are found at intervals. The 24-foot bed of limestone in the section in Gilmore Canyon contains *Spirifer cameratus*, and the 8-foot bed of limestone near the top of the formation in the same section yielded an abundant fauna of the following species, as 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.

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

From a limestone in the middle of the formation on slopes of the Laramie Mountains 20 miles north of Laramie were obtained *Productus semireticulatus*, *P. cora*, *Archæocidaris* sp., and *Pinna* sp.; in the upper limestone 2 miles east of Laramie, *Bellerophon* sp.; in the lowest limestone near the top of the mountain 6 miles east of Laramie, *Meekella striaticostata*, *Spirifer cameratus?* and *Bellerophon* sp.; in the upper limestone a mile north of Satanka, abundant *Orthotetes* sp.; and in the lower limestones near the head of Gilmore Canyon 8 miles southeast of Laramie, *Spirifer cameratus*. These were all determined by G. H. Girty and are of Pennsylvanian age.

Arnold Hague reported fossils (Pennsylvanian) from Sybille Creek, Cheyenne Pass, and a point 5 miles northwest of Sherman.[a] At the first of these places the fossils were found throughout a range of 200 to 300 feet of limestones beginning about 200 feet above the granite; the second locality was at about the same horizon; and the third was in the lowest limestone, which lies on a thin mass of basal red sandstone. Fossils have recently been discovered in basal beds along the Colorado state line by geologists of the Colorado Geological Survey. They have been identified by G. H. Girty as *Cranæna subelliptica* var. *hardingensis*, *Spirifer centronatus*, and *Spiriferina solidirostris*, all Mississippian forms. They occur in chert nodules 2 inches to a foot in diameter included in conglomeratic sandstone a few feet above the granite. They appear to be in place, but this important consideration has not yet been decided. If in place they indicate that the Mississippian series is represented in the base of the Casper formation in the southern portion of the Sherman quadrangle. The northern limit was not ascertained, but the fossil-bearing chert nodules were traced for a few miles southward in Colorado.

Correlation.—From its character and stratigraphic relations the Casper formation is believed to represent the greater part of the Tensleep and Amsden formations of the Bighorn Mountains, the Minnelusa formation of the Black Hills, and the Hartville limestone of the Hartville uplift. The three formations last named are mainly of Pennsylvanian age, but their lower beds represent the Mississippian series. The presence of red shale and cherty limestone with Mississippian fossils at the base of the Casper formation in the northwest corner of Albany County and the widespread occurrence of an upper member of gray sandstone are in accord with this correlation. Owing to upward overlap at the base of the Casper formation in areas farther south the lower member does not extend far south of latitude 42°, so that beds representing the Mississippian series do not reach the Laramie and Sherman quadrangles. Near Laramie, as stated above, Pennsylvanian fossils occur in the lowest limestones a few feet above the granite. Farther south, along the east side of the Front Range in Colorado, the Casper formation is represented by the Lyons and Fountain formations.

SATANKA SHALE.

The Satanka shale lies between the Forelle limestone and the Casper formation along the west slope of the Laramie Mountains. It is named from Satanka siding, which is situated a short distance east of its outcrop zone. At the mouth of Gilmore Canyon the formation is 232 feet thick and consists of sandy red shale with thin layers of soft red sandstone, all closely similar to much of the Chugwater formation. Its character is uniform throughout and its outcrop is generally marked by a shallow valley at the foot of the long sandstone or limestone slopes of the mountains. The valley has a low but distinct ridge of Forelle limestone on its west side. The Satanka shale outcrops almost continuously from township 17 past Laramie and Red Buttes to Sportsman Lake, but on some of the divides it is covered by high-terrace gravels or talus. East of Laramie the shale lies on limestone that forms the top of the Casper formation, but farther north and south it rests on massive gray sandstone. The shale is absent in the region between Sand Creek and Red Mountain, where the Forelle limestone lies directly on light-colored sandstone that is believed to be at the top of the Casper formation. It is possible, however, that this sandstone represents the Satanka shale, and the formation may also be represented at the base of the Chugwater formation on the east side of the Laramie Mountains.

Local deposits of gypsum occur in the Satanka shale south of Red Buttes. At the plaster mill one bed, now worked, is 15 to 20 feet thick, and 25 feet higher is another bed, 10 feet thick, which was formerly worked. The upper bed appears again half a mile farther north, near the Union Pacific Railroad. A 10-foot bed of gypsum was found in the shales not far below the Forelle limestone 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 adjoining formations.

FORELLE LIMESTONE.

Outcrop and character.—The Forelle limestone, which outcrops along the west slope of the Laramie Mountains, is named from Forelle station, south of Laramie, where it ranges in thickness from 4 to 20 feet and gives rise to a low ridge lying a short distance west of the main slope. The shallow intervening valley is due to the Satanka red shales, 200 feet or more thick, which underlie the limestone and separate it from the top of the Casper formation. These rocks are mostly covered by detritus in township 17, but the outcrop of the limestone extends almost continuously from the north side of township 16 (sec. 2) to Sportsman Lake. It passes a short distance west of the great springs 2 miles east of Laramie and is crossed by the railroad at Forelle and Red Buttes. In sec. 11, T. 16 N., R. 73 W., the limestone is in part highly gypsiferous and a short distance below it there is a bed of pure gypsum which was found to be 10 feet thick in a pit in sec. 2. In the railroad cut just south of Forelle, where the limestone is best exposed, it is heavily bedded and nearly 20 feet thick. Near Red Buttes and from that locality southward to Sportsman Lake the rock becomes gypsiferous and varies in structure from massive to thinly laminated. In places it is brecciated. It also lies in several beds, some of which locally give place to shale.

The Forelle 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 and in the Red Mountain–Ring Mountain region, where the lower red shales are absent and the limestone lies directly on sandstone. Apparently it is the Forelle limestone that immediately underlies the 67-foot bed of gypsum in Red Mountain and that yielded the numerous fossils discovered by W. C. Knight. On the slopes 2 miles south of Ring Mountain the limestone under the gypsum is thin but it contains distinctive fossils.

Fossils and correlation.—In the exposures from sec. 2, T. 16 N., R. 73 W., north of Laramie, to sec. 7, T. 13 N., R. 73 W., beyond Red Buttes, the Forelle limestone contains *Myalina perattenuata* and fragmentary remains of other species not identified. The supposed Forelle limestone just below the gypsum bed 2 miles south of Ring Mountain afforded great numbers of *Aviculipecten occidentalis*, *Myalina perattenuata*, *Allorisma terminalis*, and *Schizodus compressus*. The limestone believed to represent the Forelle formation in the Red Mountain section consists mostly of casts and impressions of fossils, specimens of which were collected by W. C. Knight in 1902.[a] According to Dr. Girty they comprise *Solenomya* n. sp., *Deltopecten manzanicus*, *D. coreyanus?*, *Schizodus meekanus*, *Pleurophorus* aff. *P. taffi*, *Dentalium canna*, *Orthonema?* sp., and *Myalina perattenuata*.

This fauna is regarded by Girty as late Pennsylvanian or possibly as equivalent to that of the lowest limestones of the so-called Permian of Kansas. Were it not for this evidence the limestone and shales would be regarded as a portion of the Chugwater formation, for near Laramie and Red Buttes the stratigraphic succession is strongly suggestive of Minnekahta limestone lying on Opeche shale. The Minnekahta limestone, which occurs south of Douglas on the east side of the Laramie Mountains and in the Black Hills, contains a different fauna from that of the Forelle, but perhaps the difference is due only to different conditions of deposition.

It is possible, on the other hand, that the Forelle beds represent the Embar formation of the Owl Creek–Bridger uplift,[b] but they lack the distinctive *Spiriferina pulchra*.

TRIASSIC (?) SYSTEM.

CHUGWATER FORMATION.

It is not definitely known that there are rocks of Triassic age in southeastern Wyoming, but as the extensive series of red beds have long been supposed to belong in the Triassic system they may be so regarded until evidence is obtained on which they can be properly classified. As in other portions of Wyoming the rocks are red shales and sandstones. They are comprised in one formation, which has been designated Chugwater, from the extensive exposures on Chugwater Creek, on the east slope of the Laramie Mountains.

Outcrop and general relations.—The red shale and soft red sandstone of the Chugwater formation outcrop in a broad zone along the west side of the Laramie Mountains and appear at intervals in the foothills on the east side. Wide areas are exposed in the region west of Sand Creek, especially about Red Mountain, which is named from the prominent outcrops of red rocks on its northern slope. The most extensive exposures on the east side of the mountains lie between the North and the South forks of Lodgepole Creek and in a narrow but nearly continuous outcrop extending from the southernmost to the northernmost prongs of Horse Creek. Small exposures appear on the North and Middle forks of Crow Creek and at the Colorado boundary. In the southern portion of the Laramie Basin the formation comprises the upper half of the "Red Beds," the lower half being the Casper formation. The average thickness is about 1100 feet. In the Laramie region and to the south and southwest the formation lies on the Forelle limestone; east of the Laramie Mountains it lies on limestones and gray sandstones of the Casper formation. The line of demarkation between is not everywhere clear and may differ in horizon in different parts of the region. East of the Laramie Mountains the formation is about 1000 feet thick except north of Horse Creek, where locally it is less than 800 feet thick. Gypsum is a characteristic feature in the Chugwater

[a] U. S. Geol. Expl. 40th Par., vol. 2, Descriptive geology, 1877, pp. 76–77.

[a] Op. cit., p. 419.

[b] Darton, N. H., Geology of the Owl Creek Mountains: S. Doc. No. 219, 59th Cong., 1st sess., 1906, p. 17.

formation, occurring in beds that range in thickness from a few inches to 67 feet. Thin beds of limestone also occur, especially in the lower beds east of the Laramie Mountains.

Local features in the Laramie Basin.—The Chugwater formation consists mostly of red shales and fine-grained red sandstones, but includes a subordinate amount of lighter-colored sandstone, thin beds of limestone, and deposits of gypsum. The gypsum beds near Red Mountain are especially thick and prominent. 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 given its name to that body of water. (See fig. 6, illustration sheet.) In localities where the dips are steep the outcrop of the sandstones presents many ragged ledges of considerable prominence. In the southern portion of the Laramie Basin the formation is so largely covered by Quaternary deposits that complete sections are rare, but all the beds are exposed in the north wall of Red Mountain. At this place the formation is supposed to comprise all the strata between the fossiliferous limestone (Forelle) underlying the gypsum and the base of the typical Morrison.

Section of Chugwater formation in Red Mountain, Wyoming.

	Feet.
Light sandstone, underlying shale and limestone of Morrison formation	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
Light shale	22
Heavy, flaggy light to buff sandstone and light shale	30
Pink massive fine-grained sandstone	24
Reddish salmon-colored sandy shale	35
White flaggy sandstone and red shale	45
Massive, cross-bedded, fine-grained salmon-colored "monument" sandstone	15
Flaggy, white sandstone and reddish shale	20
Massive, cross-bedded, fine-grained salmon-colored "monument" sandstone	65
Red shale and red flaggy sandstone; some gray beds	450
Red gypsum, nearly pure	6
Sandy red shale	35
Gypsum	3
Red shale	10
Gypsum	4
Sandy red shale	55
Fine purple-banded, wavy gypsiferous limestone	5
Red sandy shale with aragonite crystals and gypsum	88
Gypsum; pure, massive	67
	1133

In this section the upper limit of the Chugwater formation is placed arbitrarily at the base of the blue shale below the lowest limestone containing Morrison fresh-water fossils. The upper part of the Chugwater thus includes about 200 feet of alternating terra-cotta, blue, and buff shales and light-colored sandstones which are not typical and are absent in the region to the northeast; but they appear more likely to belong in the Chugwater than in the Morrison formation. It is possible that they are a local basin of Sundance (Jurassic). The gypsiferous member at the base of the Chugwater formation, here 273 feet feet thick, consists of alternating beds of gypsiferous limestone and red shale, with a massive bed of pure gypsum 67 feet thick at the base. In the red clay 20 feet above the gypsum numerous crystals of aragonite occur in hexagonal prisms, mostly short prismatic to tabular, and in penetration twins of tabular form. According to Knight they are all pseudomorphic after hanksite. The 450 feet of typical red beds above the gypsiferous measures consist of alternating red shales and red flaggy sandstones, with many thin white or pale-green layers. The 378 feet of beds next above consist of massive, fine-grained salmon-colored sandstone with a minor amount of red shale. The sandstones weather with rounded outlines and their erosion forms resemble those of the "monument" sandstones of the Casper formation.

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 points east and south of that place. At the bottom of these exposures there is a wavy gypsiferous limestone, supposed to be the Forelle. This supposition is strengthened by the occurrence of aragonite crystals on the hill slope above the limestone in this vicinity in a position similar to the one they occupy in the Red Mountain section. A mile southeast of Sportsman Lake there is an outcrop of gypsum, apparently underlain by a wavy gypsiferous limestone, which can be traced northward with certainty into the outcrop of Forelle limestone that is crossed by 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 to be in red beds and gypsum measures, which doubtless lie above that limestone.

East side of Laramie Mountains.—On the east side of the Laramie Mountains the Chugwater formation presents its usual features. In the exposure near the state boundary it is about 900 feet thick, comprising 385 feet of red sandy shale and soft red sandstone; 50 feet of gypsiferous beds, thin limestone, and red shale; and at the top 450 to 500 feet of red sandstone and shale. On the southernmost prong of Horse Creek the formation is 1000 feet thick. About 100 feet above its base is a 15-foot bed of slabby limestone resembling the Minnekahta limestone. On South Fork of Horse Creek there is a 50-foot bed of massive gray sandstone at the top of the formation, a feature often noticeable in Colorado. Possibly this member may belong to the Sundance formation. In Horse Creek canyon, where the beds are vertical, the thickness of the formation is slightly greater, owing to the thickening of a basal member of red shale and thin-bedded sandstone. On this lies a 20-foot bed of dolomitic limestone, which gives rise to a small but prominent ridge that extends some distance northward. The following section was measured at this locality:

Section of Chugwater formation on Horse Creek 1½ miles northwest of Horse Creek station, Wyoming.

			Feet.
Pale reddish-brown massive sandstone			40
Bright-red sandy shale and soft, thin-bedded sandstone			660
White, massive, fine-grained limestone			5
Bright-red shale			100
Porous dolomite			4+
Bright-red shale			70
Limestone; massive, gray above; thin-bedded, purplish below			20
Bright-red shales and sandstones			260
Pale reddish, massive, soft sandstone	20 ft.	Casper?	
White, hard, massive limestone	5 ft.		
Pale reddish-brown, massive, soft sandstone	40 ft.		
			1159+

Just south of the North Fork of Horse Creek the Chugwater formation contains a thin bed of limestone about 100 feet above its base, probably a continuation of the 20-foot bed of the above section, with diminished thickness of the underlying shale. This diminution of thickness continues northward to Chugwater Creek, the type locality, a short distance north of latitude 41° 30′, where the formation is between 700 and 800 feet thick.

Age.—The age of the Chugwater formation is not definitely known but has been supposed to be Triassic, at least in part. In other portions of Wyoming the formation includes in its lower portion a limestone (Minnekahta) known to be Permian, in the sense in which that term has been used in the Mississippi Valley, and in the Bighorn region supposed Permian fossils occur in a limestone 150 feet below the top of the formation. The fact that there are similar red beds below it in the Casper formation in the southern portion of the Laramie Basin throws no light on its age, for in this area, as in others, the deposition of red materials may have continued from Pennsylvanian through Permian and into or through Triassic time.

JURASSIC SYSTEM.

Marine deposits of Jurassic age appear extensively in central and northern Wyoming, as well as in the Black Hills and Montana. They consist of 100 to 300 feet of sandstone and greenish shale, which are remarkably uniform in character over the entire area. They have been named the Sundance formation, from Sundance, in the Black Hills uplift, where they are exposed in typical form. In the northern part of the Laramie Basin this formation thins out and disappears near Rock Creek, but on the eastern slopes of the Laramie Mountains it extends a short distance into Colorado. It is possible that the formation is represented by the 200 feet of light-colored shales lying between the Morrison formation and the top of the red beds of the Chugwater formation in Red Mountain and vicinity. As no fossils were found in these beds, however, it is not desirable to classify them as the Sundance, which at all other places is abundantly fossiliferous.

The Morrison formation, which by some geologists is regarded as Jurassic, is described under the heading "Cretaceous system."

SUNDANCE FORMATION.

The thin southern margin of the Sundance formation extends across the east side of the Sherman quadrangle, where it outcrops at intervals along the foothills. The exposure is almost continuous from North Fork of Horse Creek to the southernmost prong of Horse Creek and from North Fork to South Fork of Lodgepole Creek. Small exposures appear on North and Middle forks of Crow Creek. The rocks are mostly light-buff sandstones but include some sandy shales. The average thickness of the formation is 40 feet. In the first canyon south of South Fork of Horse Creek the rocks are mostly hard buff sandstone, which rises in a low ridge above the Tertiary deposits. The upper third is slabby and includes some buff to greenish sandy shales. On South Fork of Horse Creek, where the formation is 60 feet thick, it consists of slabby buff to gray sandstone, sandy shales, and grayish-green shales. It lies on a 50-foot bed of massive gray sandstone, which is regarded as the top of the Chugwater formation. South of Horse Creek canyon the lower 30 feet or more is greenish sandy shale, above which lies 10 feet of bright-buff soft sandstone, which extends to the base of the Morrison formation.

Fossils occur in small numbers in some of the beds. The forms collected comprise *Belemnites densus*, *Gryphæa calceola*, and *Pentacrinus asteriscus*, of late Jurassic age and characteristic of the formation in other areas.

CRETACEOUS SYSTEM.

Rocks of Cretaceous age underlie the Laramie Basin and the Great Plains east of the Laramie Mountains. Their thickness is about 6500 feet and the formations comprise the usual succession—the Morrison, Cloverly, Benton, Niobrara, and Montana. There appears to have been an uninterrupted sequence of sedimentation from earliest Cretaceous to very late Cretaceous time, except, perhaps, during the intervals represented by slight unconformities at the base and the summit of the Cloverly formation. The Morrison formation is provisionally included in this succession, for reasons that will be stated under the heading "Fossils and age."

MORRISON FORMATION.

Outcrop and character.—The main outcrop of the Morrison formation extends along the east side and around the south end of the Laramie Basin, and the formation also appears along the foothills on the east side of the Laramie Mountains. In the greater part of the Laramie Basin the Morrison formation lies unconformably on the Chugwater red beds, but east of the Laramie Mountains the Sundance formation comes between the two.

The Morrison deposits are mainly hard clay or massive shale, ranging in color from pale greenish to maroon and having a peculiar chalky appearance. The prevailing tint is pale olive-green. They include also thin beds of drab limestone and a few layers of light-colored sandstone. In places there are also concretionary masses, 2 inches or less in thickness, of olive-green to dark-green brittle siliceous rock. Some of the most extensive exposures of the formation are west and southwest of Red Buttes, west of Downey Soda Lakes, and at Red Mountain. On the east side of the Laramie Mountains there is an almost continuous outcrop of the formation from South Fork of Lodgepole Creek to North Fork of Horse Creek, but most of the exposures are poor.

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 a 1-foot limestone layer containing fresh-water fossils. Below the base of the formation there is a series of light-colored sandstones and terra-cotta and bluish shales which may possibly represent the marine Jurassic but which, as they contain no fossils, have been provisionally placed in the Chugwater.

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

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

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. At the base is 3 feet of dark shale, then 20 feet of soft, massive light-colored sandstone, and finally 10 feet of gray shale including 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 where the lower beds are soft, massive, buff sandstone. These are overlain by gray and greenish-gray massive shale or clay with thin limestone, cherty, and sandstone layers. One of the sandstone layers is 2 to 3 feet thick. At the top is very dark shale, which has been prospected for coal. It is overlain by coarse sandstone that forms the base of the Cloverly formation.

On the east side of the Laramie Mountains the Morrison formation presents its usual characteristics. In the first canyon south of South Fork of Horse Creek there is at its base 30 feet of light-colored massive shale containing several layers of limestone. One of these layers, 6 feet thick, is marked by a small ridge. Above is pale-green and maroon massive shale. On the South Fork of Horse Creek the 6-foot limestone member is again conspicuous and is underlain by 20 feet of gray shale that rests on a 1-foot limestone bed at the supposed base of the formation. The total thickness here is about 200 feet, which appears to be the average amount in other sections except on the southernmost prong of Horse Creek, where it is less than 150 feet.

Fossils and age.—Large numbers of dinosaurian bones have been obtained from the Morrison formation in southeastern Wyoming, notably from the extensive bone quarries near "Bone Cabin," in the northeastern portion of the Freezeout Hills, as well as on Como Ridge and on Bone Creek. They comprise *Brontosaurus*, *Morosaurus*, *Diplodocus*, *Stegosaurus*, *Camptosaurus*, *Laosaurus*, *Dryosaurus*, *Ornitholestes*, and *Allosaurus*. Collections have also been made 2 miles west of Steamboat Lake. Bones have been found at a point 2 miles east of Red Mountain, at several localities in Colorado a short distance south of the state boundary, and in the slopes just west of

Downey Soda Lakes. In the drab, brittle, impure limestones occurring in the Morrison formation there are found at many places numerous remains of fresh-water mollusks, which are usually of very small size. Fossil algæ occur in the limestone beds on the east side of the Laramie Mountains, but they were not observed in the Laramie Basin. Collections of mollusks made at several places have been identified by T. W. Stanton, as follows: West of Downey Soda 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."

The fossil bones from the Morrison formation have been regarded as late Jurassic by some paleontologists, but several eminent authorities now believe that they are early Cretaceous, a determination that is in accord with the close stratigraphic connection between the Morrison and the overlying Cretaceous sandstone from Montana to New Mexico.

CLOVERLY FORMATION.

Outcrop and relations.—The outcrop zone of the Cloverly formation extends all along the east side and across the south end of the Laramie Basin. There are prominent exposures west of Red Buttes and in the ridges between Downey Lakes and Jelm Mountain. Small outliers cap Red Mountain and the ridge next east, and there are small outcrops at points 2 miles west and 6 miles northwest of Laramie. On the east side of the Laramie Mountains the Cloverly formation gives rise to a line of small ridges which extends from North Fork of Horse Creek to the southernmost prong of that creek. (See fig. 11, illustration sheet.) Small exposures occur on the north sides of the North and South forks of Crow Creek and at the fault a mile south of South Fork of Lodgepole Creek. In the intervals and in the area farther south the outcrop zone is covered by Tertiary deposits. There is an abrupt change from Cloverly to Morrison beds, but probably no notable unconformity. There is considerable evidence of planation unconformity between the Cloverly and Benton, especially in regions north of the Laramie Basin.

The Cloverly formation ranges in thickness from 50 to 236 feet in the Laramie Basin, but the average amount is about 120 feet. It consists as a rule of two thick sandstone members, separated by 30 to 50 feet of buff and purplish sandy clays. The lower sandstone generally includes more or less conglomerate, especially in its lower portion, with pebbles of varicolored chert and jasper. It is the most prominent member topographically, giving rise in many places to prominent hogback ridges, notably the ridges west of Red Buttes and west and southwest of the Downey Soda Lakes.

There is an extensive and complete exposure of the Cloverly rocks in the anticline on the south side of Hutton Lake, where they appear in nearly vertical beds that run out into the lake in a prominent point. The following is a section at that place:

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; in part dark gray, in 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.	
	236½

In the hill 2 miles south-southwest of Howell station, where the Cloverly is only about 50 feet thick, it consists of two massive coarse hard sandstone members separated by dark shale which has been prospected for coal.

On the east side of the Laramie Mountains the Cloverly presents its usual characters. In the small exposure northwest of Hecla the following beds appear:

Partial section of Cloverly formation near Hecla, Wyo.

	Feet.
Flaggy buff sandstone	10
Shale, mostly concealed	20
Buff sandstone	14
Soft white sandstone	12
Soft shaly sandstone	8
Conglomerate, on Morrison	10
	74

South of North Fork of Horse Creek the Cloverly formation is about 100 feet thick and consists of the two sandstone members separated by shale. Near Horse Creek the Cloverly formation is made up of soft sandstone and is not well exposed, but the lower sandstone of the Benton, here hard and thick, gives rise to a more prominent ridge.

Age.—The Cloverly formation in southeastern Wyoming is believed to represent the same formation in the type locality—Cloverly, in Bighorn Basin. It has similar stratigraphic relations and character and has been traced almost continuously from the Bighorn Mountain region. It was formerly called the Dakota sandstone, but probably only its upper sandstone member is true Dakota, or Upper Cretaceous. The medial clay is believed to represent the Fuson, and the basal sandstone the Lakota of the Black Hills, both Lower Cretaceous, as is shown by abundant plant remains. No fossils have been discovered in the Cloverly formation in southeastern Wyoming, but a short distance farther south, in Colorado, fossils of the Comanche series have been found in the medial shale.

COLORADO GROUP.

BENTON SHALE.

Occurrence, relations, and character. — The dark Benton shale outcrops at intervals from the foot of Jelm Mountain northeastward past Laramie and through Wyoming station, but owing to its softness it has been deeply eroded and largely covered by Quaternary deposits. It is extensively exhibited in the vicinity of Hutton Lake, 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 station. It extends along the east side of the Laramie Mountains, but south of Lodgepole Creek it is mostly covered by Tertiary deposits. There are numerous exposures in the slopes adjacent to Horse and Lodgepole creeks and their branches.

The Benton shale appears to lie on the Cloverly formation with some slight unconformity but is succeeded conformably by the overlying Niobrara limestone. In the southern part of the Laramie Basin the thickness is 700 feet, to judge by the drill hole 2 miles northwest of Hutton Lake, which began near the top of the formation and reached the Cloverly at a depth of 600 feet. The thickness of the Benton shale on the east side of the mountains in the Horse Creek region ranges from 700 to 1000 feet.

The formation consists mainly of gray to black shales. The middle or Greenhorn limestone member, which is characteristic in the Black Hills region and Colorado, appears only as a thin layer along the east side of the mountains. About 200 feet above the base is the Mowry shale member. This consists of 80 to 100 feet of hard shale and thin-bedded, fine-grained sandstone which weathers to a light silvery-gray color and contains large numbers of fish scales. Owing to its hardness this member gives rise to rounded ridges of considerable prominence. A sandstone member near the top of the formation is also characteristic.

Details in Laramie Basin.—The Mowry shale member is especially conspicuous in the slopes east of Jelm Mountain, east and northeast of Hutton Lake, and southwest of Howell. An outcrop appears in slopes and brick-clay pits 2½ miles due west of Laramie. Near the top of the Benton there is a bed of sandstone which is at some 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 there are, 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 are 100 feet of the Mowry shale member, 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. 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 beds below the Mowry shale 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 Benton beds consist of 5 feet of black shale, 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 shale overlain by 30 feet of yellowish or gray shales, upon which lies 10 feet of flaggy buff sandstone containing impressions of long, narrow, willow-like leaves. On the southeast side of Hutton Lake the lower Benton beds are exposed, dipping steeply and lying on the Cloverly formation. At the base is 100 feet of dark shale with many oval concretions and a few thin sandstone layers, then 25 feet of gray sandstone overlain by 30 feet of dark shale, on which lies the Mowry shale member, 100 feet or more thick. On the east bank of Sand Creek near the middle of the north side of sec. 2, T. 13 N., R. 75 W., the lower member of the formation includes a bed of bentonite, 4 feet thick, underlain by 7 inches of soft gray sandstone. A bed of bentonite also appears in the vicinity of Hutton and Creighton lakes.

Details east of Laramie Mountains.—On the east side of the Laramie Mountains the Benton consists mainly of shale, but several members are recognizable. The Greenhorn limestone, so well developed in other regions, is doubtless represented by a thin layer of impure slabby limestone containing the characteristic *Inoceramus labiatus.* The Mowry shale member is distinct, and near the base of the Benton there is a hard sandstone, 15 to 25 feet thick, which in many places rises in small, sharp ridges that may be more conspicuous than those made by the Cloverly formation. A representative section in vertical beds near Horse Creek is given below. Some of the measurements are uncertain, owing to talus or crushing.

Section of Benton formation west of Horse Creek station, Wyoming.

	Feet.
Carlile shale member:	
Black shale, overlain by Niobrara limestone	10
Sandstone and sandy shale	20
Gray shale with concretions containing *Prionotropis* near top	200
Greenhorn limestone member:	
Sandy limestone with *Inoceramus labiatus*	¼
Graneros shale member:	
Shale, dark and fissile below	350
Hard shale and thin-bedded fine-grained hard sandstone, weathering light gray; many fish scales (Mowry shale member)	80
Dark shale	30
Hard coarse sandstone, massive	25
Dark shales, fissile to soft, resting on Cloverly sandstone	150
	865¼

The presence of the Greenhorn limestone makes it possible to subdivide the Benton in this vicinity, as in the Black Hills and in eastern Colorado, but the divisions are not separately mapped. This limestone was traced northward across Colorado from the type locality in Arkansas Valley nearly to the Wyoming line, with gradually diminishing thickness. Near North Fork of Horse Creek it is about 1 foot thick but yielded no fossils. At this place there is at the top of the Benton 15 feet of slabby gray sandstone with some shale, then 20 feet of shale with oval concretions. The top of the Mowry shale member lies 500 feet below the base of the Niobrara in this vicinity. Next below the Mowry beds is about 30 feet of black shale, and below this is 25 feet of fine-grained hard white sandstone, which is separated from the Cloverly by 200 feet of black fissile shale.

Fossils.—The principal fossils of the Benton shale are the very numerous fish scales in the Mowry 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 sandy concretions near the top of the formation contain *Prionocyclus* and *Prionotropis*, gasteropods which are characteristic of the upper portion of the Benton in a wide area of the Rocky Mountains and Great Plains provinces.

NIOBRARA LIMESTONE.

The Niobrara limestone outcrops at intervals from the foot of Jelm and Sheep mountains northeastward nearly to Wyoming station and extends along the east side of the Laramie Mountains. For much of its course, however, it is buried beneath later deposits and outcrops are scarce. The most extensive ones are at the south end of the Big Basin, in the east and west portions of the Big Hollow, in bluffs along Laramie River west and north of Hutton Lake, and at intervals from Lodgepole Creek to the North Fork of Horse Creek east of Laramie Mountain. Small exposures appear on North Fork of Crow Creek; at a point halfway between North and Middle forks; 3 miles west of the summit of Red Mountain; and on the east slope of Sheep Mountain, where the formation is faulted against the "Red Beds."

As in its type locality, at the mouth of Niobrara River, the formation consists largely of impure chalk rock, which weathers bright yellow and contains large numbers of *Ostrea congesta*. In the region west of Laramie its 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 thick. In the middle of the formation in this region there is a deposit of dark-gray shale. The chalk rock occurs in beds ranging from thin layers to slabs 2 inches thick, and at some places it is sufficiently hard to give rise to buttes of considerable prominence, as in the west end of the Big Hollow and in the bluffs overlooking Big Basin 5 miles northwest of Laramie. The bright-yellow color of these bluffs makes them conspicuous features. According to L. W. Trumbull the Niobrara chalk 8 miles southwest of Laramie contains 75 per cent of carbonate of lime, 10 per cent of silica, and 6 per cent of alumina. The amount of iron is small.

West of Horse Creek station the formation is 375 feet thick and consists of limestone and calcareous shales. At the base is a massive bed of limestone containing *Inoceramus deformis.* Another bed of limestone occurs near the middle, and layers of impure shaly limestone which weather to a bright-yellow color appear at the top. Slabby aggregates of *Ostrea congesta* occur in many of the beds and this fossil is also disseminated through some layers. Near North Fork of Horse Creek the formation is 400 feet thick.

MONTANA GROUP.

Shales and sandstones of the Montana group occupy the large syncline northwest of Laramie and also underlie a wide area of the plains east of the Laramie Mountains. In the Laramie Basin the group consists of two formations. The lower one, which has been designated the Steele shale, is a thick mass of shale representing part at least of the Pierre. The upper one is a succession of sandstones and carbonaceous shale believed to be equivalent to the Mesaverde formation. Only the lower and middle portions of the upper formation, which will be called Mesaverde, extend into the Laramie quadrangle. On the east side of the Laramie Mountains Pierre shale several thousand feet thick is overlain by sandstones that are regarded as equivalent to the lower part of the Fox Hills sandstone. Higher beds are covered by Tertiary deposits. In both areas the shale succeeds the chalk of the Niobrara conformably but with abrupt change of material. Along the foot of Sheep Mountain the beds of this group are faulted against granite.

STEELE SHALE.

Character and relations.—The lower portion of the Montana group in the Laramie Basin consists of about 3000 feet of dark shale with some thin beds of sandstone and numerous nodular concretions, mostly sandy. These rocks are believed to represent the Steele shale, named from the type locality, Fort Steele, on North Platte River. Their thickness appears to decrease locally to about 2500 feet at the south end of Big Basin. Few of the sandstone beds are more than 5 feet thick, and they are separated from one another by 100 to 300 feet or more of dark shale. At the top these sandy beds are much more numerous and constitute a thin passage series into the overlying Mesaverde, a feature well exhibited near the J. Ernest ranch and in the slopes north of Lake Hattie and south of James Lake. The principal exposures in the Laramie Basin are northeast of Lake Hattie and at the west end of the Big Hollow. Smaller ones are on the south side of Big Basin, at a few points along the north side of Little Laramie River, southeast of James Lake, and on the south side of the ridge west of Wyoming. Toward the top of the lower division there is a thin bed of hard nodular sandstone of light-gray to buff color.

Fossils.—Fossils collected from the Steele shale beds at localities west and northwest of Laramie have been determined by T. W. 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 a wide range in the Montana group. The sandy beds at the top of the formation in sec. 3, T. 16 N., R. 76 W., on the bank of Little Laramie River, yielded *Inoceramus barabini* and *Baculites compressus*, and at the same horizon on the south shore of James Lake *Nucula planimarginata*, *Lucina*, and *Cinulia* were collected. In the north bank of Little Laramie River, at a point 2½ miles north of Carroll Lake, the shales yielded *Mactra gracilis*, *Baculites ovatus*, and *B. anceps* var. *obtusus*. In upper beds of the shale a mile southeast of James Lake (SW. ¼ NW. ¼ sec. 7, T. 17 N., R. 75 W.) there was found a part of a skeleton of a large saurian which has not yet been classified.

MESAVERDE FORMATION.

Character and occurrence. — The Mesaverde formation underlies the northwest corner of the Laramie quadrangle, but much of its area is covered by alluvium and terrace deposits. Its lower bed is a prominent, moderately hard gray sandstone, about 60 to 80 feet thick, which outcrops conspicuously at the J. Ernest ranch, on the bank of Little Laramie River in sec. 3, T. 16 N., R. 76 W., and in a high point 4 miles northeast of Lake Hattie. This bed also appears a mile east of James Lake and in the west slope of Big Basin 6 miles southeast of bench mark 7159. It contains concretions of harder rock and some darker-gray layers and is overlain by about 2000 feet of soft sandstones of various kinds with but little shale. The colors vary from gray to greenish buff and some of the beds are carbonaceous.

Fossils.—In the prominent point a mile east of Table Mountain, in the lowest heavy sandstone of the Mesaverde formation, there was found the impression of a remarkable egg case of a chimæroid fish, classed by Dr. Gill in the genus *Harriotta*, which has living representatives that are all deep-sea dwellers. In a prominent bluff on the north bank of Little Laramie River at the J. Ernest ranch, in sec. 3, T. 16 N., R. 76 W., the lower sandstone yields many fossils comprising *Inoceramus barabini*, *I. sagensis*, *Avicula linguæformis*, *A. nebrascana*, and *Baculites compressus*. The first and last of these forms also occur in upper beds of the underlying Steele shale.

PIERRE SHALE.

Character and occurrence.—Owing to the extensive overlap of the Tertiary deposits in the plains east of the Laramie Mountains the Cretaceous rocks are exposed only in the deeper valleys along the foothills. The Pierre shale appears in an irregular area of moderate size on Horse Creek and its branches and in small outcrops on some of the branches of Crow and Lodgepole creeks. In the exposures about Horse Creek station, where the shales are nearly vertical, the distance is over a mile from the yellow upper beds of the Niobrara to the beginning of conspicuous gray sandstone layers. These sandstone layers are mostly soft and in part concretionary and many of them are highly fossiliferous. T. W. Stanton regards these beds as probably representing the Hygiene sandstone member of the Boulder region in Colorado. The upper portion of the formation, about 1000 feet thick, consists largely of shale and sandy shale. A 1-foot layer of brown hard slabby sandstone occurs 100 feet above the base of the shale in the slope south of North Fork of Horse Creek. A small exposure of shale overlying the Niobrara appears on McDonald's ranch, in Lodgepole Creek, but to the north, east, and south there is a thick covering of later formations. On North Fork of Crow Creek, where the entire thickness is exposed and the beds are vertical, they measure 4000 feet across but are considerably crushed and much obscured by talus. The shale is bared over an area of nearly a square mile 1½ miles farther south. It is faulted against granite and limestone of the Casper formation on its west margin and passes beneath White River beds to the east. The shale in this outcrop includes many concretions, some of which are highly fossiliferous, and thin layers of clay, ironstone, and soft sandstone.

Just east of Hecla the upper portion of the Pierre shale is obscurely exposed on the north side of Middle Fork of Lodgepole Creek, where it dips gently beneath Fox Hills sandstone.

FOX HILLS SANDSTONE.

On Horse Creek and Middle and North forks of Crow Creek the Pierre shale is overlain conformably by gray sandstone that probably represents the Fox Hills sandstone. The sandstone is mostly massive but only moderately hard and the beds are locally separated by deposits of sandy shale. The dips are gentle, to the southeast or east. Chimney Rock, on the south bank of Horse Creek 1½ miles east of Horse Creek station, is a notable outcrop of the formation. (See fig. 10, illustration sheet.) This sandstone also appears on the north side of the creek, where it extends across sec. 24. Some brown sandstone that is obscurely exposed 4 miles northwest of the station is believed to be of the same age.

The sandstone outcrops extensively along both sides of Middle Fork of Crow Creek below Hecla and in the slopes adjoining North Fork of Crow Creek. It dips gently to the east in this area and extends eastward far down the valleys, finally passing beneath the White River group. The thickness exposed is not over 600 feet.

TERTIARY SYSTEM.

Tertiary deposits underlie a large portion of the plains east of the Laramie Mountains, and remnants existing at various points in the basins and slopes west of that range indicate their former wide extent in the Laramie Basin region. One large mass occupies the slopes west and south of Ring Mountain; another fills the saddle at the south end of Centennial Valley, west of Jelm Mountain; a third lies in a basin a short distance north of the Fourmile Creek valley, its southern edge extending almost if not quite to the northern margin of the Laramie quadrangle, in R. 75 W. The deposits east of the mountains are of Oligocene and Miocene age, represented by the Brule clay and probably also by the Chadron sandstone (the basal part of the White River group), overlain by the Miocene Arikaree formation. The deposits west of the mountains are of unknown age except in the Little Medicine Creek basin north of latitude 42°, where the two formations of the White River group occupy a wide area.

OLIGOCENE DEPOSITS (WHITE RIVER GROUP).

The clays, sands, and sandstones of the White River group underlie the plains east of the Laramie Mountains and are exposed extensively near the mountains in all the larger valleys, notably along Crow, Lodgepole, and Horse creeks. They lie unconformably on various formations, which range in age from pre-Cambrian to upper Montana, on a plane that slopes eastward at a rate of about 75 feet to the mile. The rate is somewhat less on Crow Creek and it increases in places on the slopes in the larger valleys. Toward the east the top of the group passes beneath the Arikaree formation a short distance west of longitude 105°. In most parts of the northern Great Plains the White River group comprises the Brule clay above and the sands, sandstones, and fuller's earth of the Chadron beds below. These two divisions appear to be represented in the Sherman quadrangle, but the identity of the lower one could not be established by paleontologic evidence.

CHADRON SANDSTONE.

General relations.—The lower beds of the White River group so closely resemble the Chadron formation that they are provisionally correlated with it, although the usual remains of *Titanotherium* were not found in them. They consist largely of brown sandstone, which is conspicuous in bluffs and on wide tabular surfaces in the Crow Creek basin in the western half of T. 14 N., R. 69 W., on the north side of North Fork of Crow Creek, and in Horse Creek valley. This sandstone ranges in thickness from 20 to 40 feet in most areas and as a rule is decidedly hard. Some parts of it are conglomeratic, and where it approaches and overlaps the pre-Cambrian rocks it contains much coarser material. It usually lies on a small amount of coarse arkosic sand, in places merging into fuller's earth. Locally this underlying member increases greatly in thickness along the bases of the mountain slopes, and locally also the sandstone gives place to loose sand and gravel, so that its identity is lost. These features all exist together in some of the slopes south and north of Horse Creek station and southwest of Hecla.

Local features.—In the northern part of T. 17 N., R. 70 W., the basal deposit is a conglomerate or bowlder bed containing large bowlders, some of them of decomposed granite and others of limestone. A mound of Fox Hills sandstone that rises in the formation in the northern part of sec. 10, T. 17 N., R. 70 W., is capped by coarse bowlders, which probably form the basal part of the White River group. The brown sandstone appears again 2 miles south of this point, abutting against the Fox Hills sandstone. A short distance farther southeast it is underlain by about 3 feet of siliceous limestone. It extends nearly to the Horse Creek road and occurs again just southeast of Chimney Rock, together with the underlying siliceous limestone. Here the sandstone lies against the Fox Hills sandstone and thickens rapidly toward the south, giving rise to a prominent bluff which extends toward and then along the east side of the railroad nearly to the Horse-Lodgepole divide. The divide here is capped by fuller's earth, and most of the region lying farther south, as far as Crow Creek, is covered by Brule clay. The limestone at the base of the Brule clay appears on the North Fork of Lodgepole Creek a few yards east of the railroad, and obscure deposits of coarse basal beds outcrop higher up the creek. The brown sandstone outcrops begin at the foot of Mesa Mountain, a mile south of South Fork, and extend southward, appearing at intervals and attaining much prominence on both banks of North Fork of Crow Creek near the Van Tassel ranch and in the Crow Creek basin farther south.

BRULE CLAY.

Character and distribution.—The Brule clay consists largely of a mixture of clay and fine, rather hard sand, which on slopes, especially in the vicinity of ravines, is eroded into miniature badlands. Its color ranges from pale buff or yellowish gray to very pale pink. Some beds are more sandy than others and most of them contain small hard siliceous concretions, of irregular form. It includes at some localities thin local beds of sandstone and of fuller's earth. The formation appears most extensively in the long slopes rising to the plateaus east of the Colorado and Southern Railroad, especially in the valleys of Horse, Lodgepole, and Crow creeks. Wide outcrops also extend from Silver Crown southwestward nearly to Granite Canyon station. The formation appears to attain in places a thickness of about 300 feet.

The lower beds of the Brule clay lie beneath the Colorado and Southern Railroad west of Silver Crown and in the divide between Crow and Horse creeks. These beds contain considerable gravel and fuller's earth and, at a horizon near the base, a thin bed of siliceous limestone, which apparently is not continuous. Near the mountains much coarse material occurs at some places, while at others fine fuller's earth extends to and over the granite. Such an overlap of fine material was exhibited in widening the railroad cut a quarter of a mile west of Granite Canyon station, where the relations were as shown in figure 2.

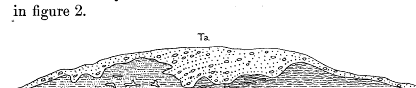


FIGURE 2.—Tertiary deposits in railroad cut one-quarter mile west of Granite Canyon, Wyoming; looking north.

Length, 100 feet; height, 20 feet. Ta, Arikaree formation; Tb, Brule clay. Granite porphyry underlies the section shown.

The lower formation is stratified pale-buff clay with scattered streaks of gravel. It includes irregular nodules of harder clay in the western part of the section and wavy lenses of light-colored calcareous claystone containing granite pebbles in the eastern part. Above are 12 feet of gravel and sand, probably Arikaree, lying on an exceedingly irregular erosion surface.

Along the Colorado state boundary just west of the east line of R. 70 the wedge-shaped western edge of the Brule clay attains a thickness of about 60 feet. The material is massive clay typical of the Brule, in part nodular, with a small amount of conglomerate at the base and an irregular streak of conglomeratic sandstone in the middle. It lies upon red beds and is unconformably overlain by arkosic grits and conglomerate of the Arikaree formation about 150 feet thick which overlap beyond its western edge. In the western part of sec. 2, T. 12 N., R. 69 W., Duck Creek has cut through the Arikaree and exposed a small knoll of underlying Brule clay. The exposure is only a few rods long and the Brule rises about 45 feet above the creek. The upper 20 feet is gray to greenish fuller's earth and the lower part is a typical massive, very pale pink hard mixture of clay and fine sand, with some harder nodules. The knoll is capped by brown grit and conglomerate of the Arikaree formation.

Fossils.—The only fossils collected from rocks of the White River group were a few bone fragments from the Brule clay near the railroad in the southern part of T. 18 N., R. 70 W. They were determined by Mr. Gidley, of the United States National Museum, as follows: Jaw fragments and teeth of *Merycoidodon* (*Oreodon*) *culbertsoni*, lower jaw of *Hyracodon cruentus*, lower premolar of *Hyracodon nebrascensis*, and two dorsal plates of *Stylemys?* sp. They are of middle Oligocene age.

MIOCENE DEPOSITS.

ARIKAREE FORMATION.

Distribution.—The table-lands east of the eastern foothills of the Laramie Mountains are capped by a sheet of sand and gravel that is in places cemented into a loose sandstone or conglomerate, which probably represents the Arikaree formation. It has been cut away by Horse, Lodgepole, and Crow creeks for 8 or 9 miles from the foot of the mountains and also in an irregular zone near the foothills across the divide north of Crow Creek. The resulting westward-facing escarpments are especially conspicuous on the divides between Horse, Lodgepole, and Crow creeks, where, with long slopes of Brule clay, they rise from 200 to 500 feet above the valleys on the west. These valleys and low divides are followed by the Colorado and Southern Railroad from Silver Crown northward to the north boundary of the Sherman quadrangle.

On the divide south of Crow Creek the formation extends high up the mountain slope and overlaps the granite at Granite Canyon, affording a long, smooth grade up the mountains for the Union Pacific Railroad. Here the formation lies on Brule clay, whose surface is usually very smooth, though in places showing slight channeling; but farther south it overlaps westward on the limestone and granite. To the east its base declines more rapidly than the floors of the valleys, so that the Brule clay disappears a short distance west of the east margin of the Sherman quadrangle in the valleys of Horse, Lodgepole, and Crow creeks. The Arikaree formation attains a thickness of 200 to 250 feet on the wide flat-topped ridges lying between these valleys.

Character. — The Arikaree formation consists largely of coarse sand and gravel, in part cemented into a loose sandstone or conglomerate. It includes a local bed of limestone in the southeast corner of the Sherman quadrangle and also, in places, some deposits of loam. Much of the coarse material is directly derived from the Sherman granite with its characteristic pinkish feldspar, and a large proportion of it, especially near the mountains, is angular or subangular. Near the Horse Creek valley it comprises a large amount of anorthosite débris, which gives it a particularly light color. Beds of coarse bowlders are numerous, especially near the mountains, but farther east the materials are all fine grained. Near the eastern margin of the quadrangle the finer-grained beds begin to show layers of nodular and cylindrical concretions, which increase in number eastward until the formation presents the characteristics of the typical Arikaree as seen in Pine Ridge and other portions of eastern Wyoming. At the base of the formation there is in most places a coarse conglomerate, shown in figure 5 of the illustration sheet. The limestone in T. 12 N., R. 68 W., in the southeast corner of the Sherman quadrangle, is a bed having an elongated oval form, trending northeast-southwest, and lying about 200 feet above the base of the formation. It is 25 feet thick on Duck Creek, in sec. 8, but thins out to the east and west. Its form suggests that it was deposited in a long, narrow lake. In some places it lies on coarse sand; in others, as on Duck Creek, where it is well exposed, it rests on conglomerate containing bowlders up to 6 inches in diameter. Many of these bowlders are sheathed by thin layers of carbonate of lime having the character of onyx. The limestone is massive and weathers out in large gray blocks. It is overlain by brown sandstone, sand, and gravel.

UNDIFFERENTIATED TERTIARY DEPOSITS.

On the high slopes south and west of Ring and Red mountains there are deposits of sand, gravel, and conglomerate, which doubtless are of Tertiary age, although no Tertiary or other fossils have been found in them. They lie at altitudes of 7800 to 8400 feet and the underlying formations range from Niobrara to granite, the latter on the west slope of Ring Mountain. The materials are an incoherent mixture of sand and gravel, derived mainly from the crystalline rocks and ranging from small pebbles to large bowlders. In places, especially near the bottom, the material is cemented into a rather firm arkose or conglomerate with a matrix largely composed of carbonate of lime. The topography of these deposits is very characteristic, consisting of low rounded hills and plains in the midst of rough ridges of granite, schist, and other hard rocks. The beds are nearly level but were laid down on an uneven surface, and their maximum thickness appears to be about 250 feet. No evidence was obtained as to the age of the deposits; on the one hand they may be as old as Wasatch, on the other they may be as young as Arikaree.

QUATERNARY SYSTEM.

Extensive deposits of Quaternary age occur in the Laramie Basin as alluvium and high-terrace gravels representing various stages of topographic development of the region. In the valleys east of the Laramie Mountains small areas of older terrace deposits and narrow areas of alluvium lie along the streams.

HIGH-TERRACE DEPOSITS.

Nearly all of the low divide ridges throughout the Laramie Basin are covered by deposits of gravel, sand, and loam, in places from 30 to 50 feet thick. They are mostly from 20 to 100 feet higher than the alluvial plains along the present valleys and represent the diversified surface of the basin at various earlier stages of its topographic development. The deposits are coarsest and thickest near the mountains and are most extensive in the vicinity of Laramie River, having been laid down by that stream and its branches during Quaternary time. In many places their lower limits are indefinite, for they slope down to the alluvium. At such places the boundaries given on the map are somewhat arbitrary, notably in the areas west of Howell, southwest of Alsop Lake, and from Lake Hattie to and beyond the Union Pacific Lakes. Older terrace deposits remain on some of the lower slopes adjoining Horse, Lodgepole, and Crow creeks, but they are thin and of rather small extent. In places it is difficult to distinguish this material from the Tertiary deposits and the local talus.

MODERN ALLUVIUM.

All the larger streams in the Laramie Basin flow through wide valleys that are filled with alluvial deposits. These deposits differ in thickness in different localities but in greater part vary from 10 to 30 feet. In general they are widest in the outcrop zones of the softer rocks and become narrow, thin, and discontinuous in the higher lands underlain by the Casper formation and the basal crystalline rocks. The widest areas are along Laramie and Little Laramie rivers, west and southwest of the city of Laramie. The larger creeks east of the Laramie Mountains are bordered by alluvium, especially Horse Creek and its North Fork above the Davis ranch. The small flood plain on Duck Creek near the McLaughlin ranch contains some alluvium, but the principal material in it appears to be Tertiary. On the east side of the Laramie Basin near Laramie and Red Buttes portions of the alluvium consist of gypsite, a fine gypsum sand derived from neighboring deposits of gypsum. The material is found in different degrees of purity, but much of it consists of 75 to 80 per cent of gypsum. The principal known deposits are on Spring Creek just south of Laramie; on Willow, Fivemile, and Harney creeks near Red Buttes; on Soldier Creek west of Forelle; at a place east of Bona; and at a place 3 miles southeast of Hutton Lake. At the plaster works at Laramie the deposit is 9 feet thick and in pits south of Red Buttes it is 5 to 6 feet thick.

STRUCTURAL GEOLOGY.

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

General statement.—The structure of the north-central portion of the Rocky Mountain province presents a succession of elongated flexures which mostly trend north and south in southern and northern Wyoming and east and west in the central part of the State. There are several long anticlines and synclines which vary considerably in form and which rise and fall at intervals. The undulations are especially irregular in central Wyoming, where the flexures trend east and west and where there are many shorter flexures of various kinds. The anticlines differ in steepness of sides, in width and flatness of top, and in altitude of crest. Ordinarily one side is steeper than the other, but overturns beyond a vertical plane are unusual, and many of the tops are flat for varying widths. Faults occur but most of them are not of the overthrust type. The principal uplifts are those of the Front Range, the Medicine Bow Mountains, the Freezeout Hills–Wind River Mountains, the Bighorn–Owl Creek Mountains, and the Black Hills, the last rising on a branch of the uplift of the Front Range that passes through the Hartville region. These uplifts bring to the surface the pre-Cambrian granites, schists, and other rocks, which are flanked by a thick series of Paleozoic rocks. The principal intervening synclines are those of the Laramie, Wind River, Bighorn, and Powder River basins, which hold from 5000 to 7000 feet of deposits ranging in age from Paleozoic to Cenozoic.

Main local features.—The dominant structural feature in the Laramie and Sherman quadrangles is the great anticline of the Laramie Mountains, a northern extension of the Front Range of the Rocky Mountains. The strata on its flanks are steeply uplifted and the sedimentary rocks in the elevated central area have been so deeply eroded that the pre-Cambrian crystalline rocks appear at the surface in a zone 10 to 15 miles wide. The vertical uplift is about 4000 feet. To the east are the Great Plains, underlain by strata that are nearly horizontal; to the west is the Laramie Basin.

The Laramie Basin is formed by 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. Because of its northward pitch it narrows toward the south and terminates a short distance south of the Laramie quadrangle, but it extends far to the north and northwest. This broad trough is traversed by a number of anticlines that start in various directions from the border of the basin and die out toward its middle. The sections in the structure section sheets illustrate the principal structural features of the Laramie and Sherman quadrangles; figure 3, below, shows the configuration of the flexures in the Laramie quadrangle. Owing to the wide areas of pre-Cambrian and Tertiary rocks east of this area it is not practicable to prepare a similar diagram of the structure of the Sherman quadrangle.

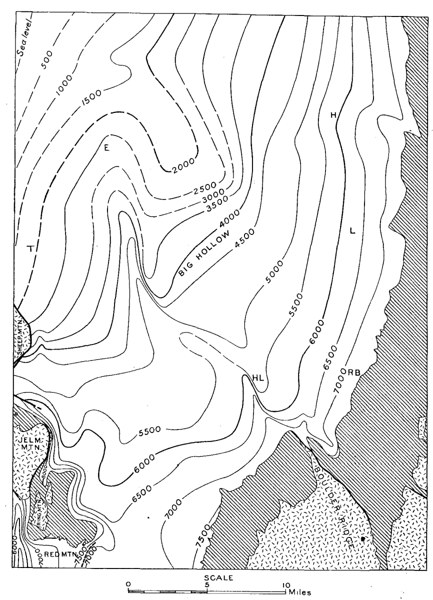


FIGURE 3.—Structure of the Laramie quadrangle shown by contours on the top of the Casper formation representing elevations above sea.

Ruled areas, outcrop of Casper formation; dashed areas, pre-Cambirian rocks. L, Laramie; RB, Red Buttes; HL, Hutton Lake; H, Howell station; E, Ernest's ranch; T, Table Mountain.

West slope of Laramie Mountains.—The strata lying along the west slope of the Laramie Mountains and constituting their summit near Laramie dip in general westward at moderate angles, the dip averaging 3° near Red Buttes, 4° near Laramie, and 6° east of Wyoming station. The strike is uniformly north and south for many miles near Laramie except for a short distance near Pilot Hill, where a small anticline and fault cause a slight offset in the ridge. In this great westward-sloping monocline the strata descend in regular order, and in the center of the basin northwest of James Lake the bottom of the sedimentary rocks is several thousand feet below the surface.

This monocline is cut by a fault near Tie Siding. This fault, so far as it is marked by contact of sedimentary rocks with the granite, is about 3 miles long, extending on a north of west course 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. No accurate measurement of its throw is possible, but as the strata dip 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 dip of the fault plane is very steep, but the plane was not actually seen and it is not known whether the fault is normal or reverse. The small fault that traverses the Casper formation east and northeast of Pilot Hill is on the axis of a 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. It merges into the anticline and is believed to be a slight overthrust, but as the outcrops are widely scattered its precise relations could not be ascertained.

East side of Laramie Mountains.—The east limb of the Laramie Mountain uplift has a steep dip and strikes nearly due north and south across the Sherman quadrangle. Near the point where the Colorado state boundary line crosses Duck Creek the dips are low, averaging about 10°, but they increase to 30° at Granite Canyon and to 45° a mile farther north and become nearly vertical from the Middle Fork of Crow Creek northward. The strata are in places slightly overturned and are also locally faulted. The amount of overturning is 5° just west of Hecla and 10° near South Fork of Horse Creek. In Mesa Mountain the monocline is flexed into a shallow syncline which spreads the Casper formation into a broad, high mesa for some distance, and in an anticline just east of that mountain the pre-Cambrian rocks extend from North Fork of Crow Creek nearly to South Fork of Lodgepole Creek. For part of the distance the east side of this anticline is faulted, but most of the structural features at the fault are obscured by Tertiary deposits. For some distance along its course the granite is in contact with the Niobrara, and at one point with the Cloverly formation. It appears again south of North Fork of Crow Creek, where Pierre and Chugwater beds are in contact, and farther south the Pierre is exposed, faulted against the granite on the east side of sec. 12, T. 14 N., R. 70 W. A short distance north of South Fork of Lodgepole Creek there are steep dips in the Casper formation on the ridge, and the syncline of Mesa Mountain is continued northward in red beds, while the anticline is in Morrison, Cloverly, and Benton beds. This anticline disappears in the Niobrara and Steele formations just southeast of McDonald's ranch. On the branches of Horse Creek the formations from Casper to Niobrara present very steep or nearly vertical dips with some local overturning to the west. Dips are also steep in the Montana beds near Horse Creek station, but they are much less steep in the outcrop zone of that group to the south and east. At Chimney Rock the strata dip 10° SE.

Boulder Ridge anticline.—In the southern part of the Laramie Basin the main syncline is divided into two troughs by a prominent anticline that extends into the basin from the south and pitches down toward 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 formations ranging from Chugwater to Benton south of Creighton Lake and in the Niobrara limestone at the west end of the Big Hollow, and its effects are also clearly marked by uplift in Montana beds for some distance farther north. In general this anticline presents very steep dips on its east side and gentle dips on its west side. The Boulder Ridge anticline is well exhibited just south of Hutton Lake, where the beds on the southwest limb dip 15° and those on the northeast limb dip 50° to 85°. The steeply dipping beds from Morrison to Benton outcrop in a prominent ridge along the south side of the lake. A small ᔕ-shaped flexure in the Mowry beds on the east limb of this anticline is clearly exposed on the south shore of the eastern part of the lake. On Laramie River the Niobrara dips to the northeast at an angle of 5° on the northeast side of the Boulder Ridge anticline and at about the same rate to the southwest on its opposite side. Benton shale 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 by extensive exposures of beds of the Niobrara, which on the east side of the flexure have nearly vertical dips, as shown in section B–B.

From the north end of the Boulder Ridge granite area to the south line of T. 13 N. the east side of the anticline is faulted. This faulting is indicated by the fact that outcrops of the limestone and sandstone beds of the Casper formation are abruptly cut off by the granite, as they swing to the west in the adjoining anticline. South of the south line of T. 13 N. the granite slopes on the east side of Boulder Ridge are 300 to 500 feet high, but they are more gentle than in the region farther north, 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 boundary. On the west side of Boulder Ridge there is a gentle slope of granite which dips beneath the Casper formation at a low angle into the wide syncline that extends to Red Mountain. In the northwest corner of T. 13 N., R. 73 W., a small anticline that runs parallel to the main flexure of Boulder Ridge is marked by curved outcrops of the Forelle limestone.

Red Mountain-Jelm Mountain area.—Jelm and Ring mountains are due to faulted upthrusts resulting in an irregular anticline, which extends along the southwest margin of the syncline that forms the Laramie Basin. This anticline comprises several axes varying in pitch but all showing a general north-south strike. Farther south, in Red Mountain and in Colorado, these axes merge into a broad area of gentle undulations that are well exhibited in beds ranging 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. This fault extends northward from Colorado and ends a few miles northeast of Red Mountain in an eastward-dipping monocline in upper Chugwater beds and overlying formations. North of Red Mountain there is a prominent rise in the anticlines along three subordinate axes so that the granite and schists are brought up in Ring and Jelm mountains and in a ridge lying northeast of Ring Mountain. The easternmost of these axes bears to the northeast and with but slight pitch continues to Laramie River, which it crosses east of Olson's ranch. In the river bottom the rocks are covered by alluvium, but the flexure appears again in the Benton and Niobrara formations in the terrace slope near bench mark 7366. The syncline west of the flexure gives rise to a succession of U-shaped outcrops of the strata in the slopes just east of Jelm Mountain. At the north end of Jelm Mountain the strata pitch steeply to the north and about $1\frac{1}{2}$ miles north of Laramie River are cut off by a fault that crosses the south end of Sheep Mountain in the next quadrangle west. On the east and west sides of Jelm Mountain there is considerable faulting, the relations of which are not exposed, and perhaps also some overlap of the Chugwater formation beyond the edge of the Casper formation. West of Ring Mountain and farther south the relations are hidden by Tertiary deposits except on the west side of the Red Mountain area, where strata ranging from Morrison to Niobrara dip to the west.

Sheep Mountain faults.—For many miles along the west side of the Laramie Basin there is a great fault which brings the beds of the Montana group and the pre-Cambrian rocks into contact. Throughout most of its course this fault lies west of the Laramie quadrangle, but in T. 15 N., R. 77 W., it bends toward the east and the granite which it uplifts gives rise to Sheep Mountain. The principal features of this fault are shown at the west ends of sections B–B and C–C of the structure-section sheet. West of Lake Hattie sandstone of the Mesaverde formation dipping gently westward is in contact with granite at the base of Sheep Mountain, indicating a throw of about 5000 feet, the maximum amount. The throw of the fault diminishes toward the south and Steele shale and Niobrara limestone rise to the surface along its east side. The relations at the southeast slope of the mountain are obscured by a heavy talus which merges down into high-terrace deposits. At one point some red beds, presumably Chugwater, appear near the granite, and a short distance east there are small outcrops of Niobrara, both dipping west about 70°. Apparently these features are due to a split in the fault. A mile farther south small exposures of Niobrara and Benton abut against beds of the Morrison formation along the fault above mentioned, which trends northwest and crosses the south end of Sheep Mountain. This fault passes southeastward beneath the high-terrace deposits and probably dies out before reaching Laramie River.

Great Plains.—The Tertiary formations that underlie the Great Plains dip eastward at angles so low that their slope is not perceptible. From Crow Creek northward the Brule and Chadron beds dip at the rate of 90 or 100 feet to the mile, and the direction of maximum grade is slightly north of east.

The base of the Arikaree formation dips eastward at the rate of about 80 feet to the mile, to judge by the exposures near Lodgepole and Horse creeks. The fact that this rate of dip is greater than the slope of the valleys causes the base of the Arikaree to cross the valleys of Crow, Lodgepole, and Horse creeks a short distance west of the east margin of the Sherman quadrangle.

GEOLOGIC HISTORY.

GENERAL SEDIMENTARY RECORD.

By N. H. Darton.

The rocks appearing at the surface in the Laramie and Sherman quadrangles comprise granites, gneisses, schists, and other crystalline rocks of pre-Cambrian age and a thick series of sedimentary strata, consisting of sandstone, shale, limestone, sand, loam, and gravel, all presenting more or less variety in composition and appearance. The principal materials of which the sedimentary deposits are composed were originally gravel, sand, or mud derived from the waste of older rocks, or chemical precipitates from salty waters.

These sedimentary rocks afford a record of physical geography that extends from Carboniferous time to the present. The composition, appearance, and relations of the strata indicate in some measure the conditions under which they were deposited. Sandstones ripple-marked by waters or by wind or cross-bedded by currents and shales cracked by drying on mud flats show deposition in shallow water; pure limestones generally indicate open seas and scarcity of land-derived sediment. The fossils that the strata contain may belong to species resembling those which now inhabit waters that are fresh, brackish, or salt, warm or cold, muddy or clear, and may therefore afford suggestions as to the conditions prevailing at the time and place at which they were entombed. The character of the adjacent land may be shown by the kind of sediments derived from its waste. The quartz sand and the pebbles in coarse sandstones and conglomerates, such as are found in the Casper, Cloverly, Chadron, and Arikaree formations, had their original source in crystalline rocks and have been repeatedly redistributed by streams and concentrated by currents and by wave action on beaches. Red shales and sandstones, such as make up the Chugwater and part of the Casper formation, are as a rule the result of the revival of erosion on a land surface long exposed to rock decay and oxidation and hence covered with a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediments, the sea receiving mainly substances in solution.

The strata brought to view by the Rocky Mountain uplift record many local variations in the ancient geography and topography of the continent. The older formations exposed by the uplift were laid down in seas that covered a large portion of the central-western United States, for many of the beds are continuous over a vast area. The land surfaces of that time were probably large islands of an archipelago that was to some degree coextensive with the present Rocky Mountain province, but the relations of land and sea varied greatly from time to time and the shore lines have not been even approximately determined for any one epoch.

PRE-CAMBRIAN TIME.

By Eliot Blackwelder.

Archean (?) period.—The oldest rocks of the Laramie region yield no fossils and show no succession of sediments that indicates changes in geography or climate. Even the meager record once made has been largely obliterated by metamorphism, but there are some indications of certain early events in the region.

It is evident that volcanic activity was dominant for a time, and that both acidic and basic lavas were alternately poured out upon the surface in the form of flows and breccias. Into these were intruded from time to time many kinds of dikes and stocks, part of which may have reached the surface as later flows. Scanty accumulations of sediments also were formed, possibly during the volcanic period.

The next episode of which there is legible record was the metamorphism of these ancient rocks into schists and gneisses. That they were highly folded, crumpled, and broken is obvious, but it is doubtful whether the recrystallization of the rocks is due primarily to the deformation or to deep burial. The force that caused this folding was exerted in a line extending nearly from north to south, and was thus quite different in direction from the nearly east to west compression which, at the close of the Cretaceous period, produced most of the Rocky Mountain folds.

Apparently after the metamorphism of the schists, large bodies of granite, of at least two different kinds and ages, were intruded into them. At that time the schistose series must have been far more extensive than it is to-day. These granites dislocated and penetrated the schists and, at least near the contact with them, intensified their metamorphic features. A second episode of deformation is required to explain the gneissic structure of all these ancient granites. The possibility that the gneissic banding is an original flow structure seems to be precluded by the fact that the banding is not parallel to the edges of the gneiss but is in general nearly parallel to the older structures.

Intermediate intrusions.—After the early granitic intrusions and, in part at least, after those granites had been deformed, a variety of other igneous rocks were intruded into both granites and schists. These igneous rocks comprised diorites, gabbroids, syenites, anorthosites, and granite porphyries. The intrusions were not contemporaneous, for some of the rocks are intruded into the others as well as into the oldest rocks. These intrusions were comparatively unimportant in their effects, although around the edges of the intruded masses they increased somewhat the alteration of the schists and gneisses.

Sherman batholith.—After the last of these intrusions the most important event of pre-Cambrian time in this district was the intrusion of a vast mass of coarse-grained granite. The upper surface of this granite roughly resembles a very low dome, upon which rests a roof composed of the older rocks of the district. Around the border of this batholith the country rocks were locally brecciated on a grand scale and penetrated by thousands of granitic dikes. The metamorphism effected by the granite, however, was extraordinarily slight considering the heat of the intrusive mass and the amount of active solutions to which it must have given origin. After the upper part of the batholith had solidified cracks in the solid part were filled with additional granitic material from beneath. Thus a great number and variety of dikes and veins of granite, porphyry, pegmatite, and quartz cut through the granite and pass into the adjacent rocks.

At a distinctly later time further volcanic activity resulted in the intrusion of basic lava that formed small diabasic dikes.

Algonkian interval of erosion.—After this long-continued series of eruptions and intrusions volcanic activity in these two quadrangles ceased and was never resumed. For a long period the region was subjected to weathering and erosion as a land surface. The depth to which denudation penetrated is roughly indicated by the fact that the roof of the great Sherman batholith was largely stripped off, leaving only scattered patches of the older rocks here and there, and the granite dome itself was deeply eroded. That the topographic result was the development of a nearly base-leveled surface or peneplain may be inferred from the fact that the surface on which the Paleozoic rocks lie is remarkably smooth. Furthermore, the basal Carboniferous strata generally contain much shale and limestone rather than the coarser débris that is furnished by the erosion of a rugged surface; and even the little conglomerate found here and there at the base of the Paleozoic section is merely the reworked coarse residual soil that was derived from the granite. The surface on which the sediments were laid down therefore probably possessed no marked relief.

PALEOZOIC AND LATER TIME.

By N. H. Darton.

Early Paleozoic conditions.—In the Laramie and Sherman quadrangles the pre-Cambrian rocks are directly overlain by upper Carboniferous (Pennsylvanian) deposits, so that the long history of the Cambrian, Ordovician, Silurian, Devonian, and early Carboniferous periods is not traceable in the rocks of the region. The overlap relations of the formations of these periods in other parts of the Rocky Mountain province indicate that this area was a land surface for much of Paleozoic time. Probably there were intervals of submergence with deposition, but if so the deposits were completely removed by erosion after uplifts preceding the Carboniferous period. The presence of Middle Cambrian rocks in the Black Hills and Bighorn Mountains, in central Wyoming, and at intervals along the east side of the Rocky Mountains indicates that there were water bodies in those regions in Middle Cambrian time. The Ordovician sediments of the northern Bighorn Mountains, the Wind River Range, the Black Hills, and the eastern Front Range in Colorado were the result of submergence in those areas, but the original extent of the deposits is not known.

The general absence of Silurian and Devonian rocks in the central Rocky Mountain region is believed to indicate an extensive land area during those periods. Early Carboniferous rocks (Mississippian) approach the Laramie-Sherman area on all sides and show that in Carboniferous time the sea was rapidly encroaching on the land.

Late Carboniferous sea.—The waters of later Carboniferous time were mostly marine, and the greater part of their earlier sediments were coarse deposits such as are formed along an advancing shore line. At that time and later the old crystalline rock of the land, having been deeply decomposed and oxidized, furnished to the waters a large amount of coarse material and much red clay. When the waters had deepened somewhat limestones were formed, but there were intervals in which sands and red muds were the principal deposits, especially in the south and southwest parts of the region, where these materials greatly predominate probably because of shallower water and stronger currents in that area.

Red gypsiferous sediments.—In later Carboniferous time (Pennsylvanian and probably also Permian) there was widespread emergence of this land, resulting in shallow basins and low plains with wide mud flats, which occupied a large part of the Rocky Mountain province. In this region the last deposits of the Casper formation and the great mass of red clay and sand that constitutes the Chugwater formation were laid down. These beds, which probably were largely deposited during a period when the climate was prevailingly arid, accumulated to a thickness of 1000 feet or more. The materials of the coarser beds were carried by streams, but the finer beds were laid down in shallow local basins and on wide mud flats, as is indicated by the numerous mud cracks, ripple marks, and impressions of various kinds on many of the layers of the formation. The nearly general red tint of the deposits doubtless was the original color, for it is present not only throughout the lateral extent of the formation but also, in most beds, through its entire thickness, as is shown by deep borings. It is therefore not due to later or surface oxidation.

At various times, which were not synchronous throughout the region, the accumulation of sand and clay was interrupted by the chemical precipitation of comparatively pure gypsum in beds that range in thickness from a few inches to nearly 70 feet and that, as a rule, are free from sand and clay. It is apparent that this gypsum is the product of evaporation in lakes, and its nearly general purity indicates that the waters in which the beds were formed were quiet.

It has been supposed that the red beds of the Chugwater formation represent the Triassic period, but there is no direct evidence to sustain this supposition, and, in part at least, they are probably Permian. Their deposition appears to have been followed by extensive uplift without local structural deformation but with general planation and occasional channeling which represents a portion of Triassic time of unknown duration. This uplift was succeeded by submergence and the deposition of later Jurassic sediments.

Jurassic to Cretaceous seas.—The absence of marine Jurassic sediments in the central and southern Rocky Mountain province indicates either that this region was a land area throughout Jurassic time or that any Jurassic deposits that were laid down were removed by late Jurassic or early Cretaceous uplift and erosion. The southern margin of the area of known Jurassic deposition passed across the middle of the Laramie Basin some distance north of the Laramie quadrangle, but extended southward along the Front Range of the Rocky Mountains to a point in Colorado a few miles south of the Wyoming boundary. That this was a marine submergence is indicated by the fossils. The area of Jurassic deposition extended far to the north through Wyoming and Montana, to the northeast beyond the Black Hills, and probably a hundred miles or more east of the Laramie Mountains. The materials of the Jurassic deposits are nearly all fine grained, especially those in the upper beds, which are mostly shale, and they therefore indicate the absence of strong currents.

During the long portion of Mesozoic time that followed the epoch of marine Jurassic conditions a great series of sands and clays were deposited in formations that are generally uniform over wide areas. The earlier deposits were such as are characteristic of streams or shallow estuaries along a coastal plain; the sediments next deposited were laid down in marine waters; later, toward the end of Jurassic time, the deposits were fresh-water sands and clays with marshy vegetation. The first deposits now constitute the Morrison formation, a widespread mantle of massive sandy shale which extends from Montana to New Mexico. The Morrison beds in this province were laid down in a series of basins or troughs occupied by sluggish streams and shallow bodies of fresh water with wide mud flats, and the deposits were mixtures of clay and fine sand with thin, irregular bodies of coarser sand, deposited by streams or currents. Occasionally thin beds of impure carbonate of lime were also laid down. Huge dinosaurs were numerous, for their remains are now found in abundance in the formation.

Morrison time was succeeded, later in the early Cretaceous, by a change to widespread coastal-plain conditions, under which the coarse-grained, massive-bedded conglomerates and sandstones of the Cloverly formation were deposited. Although the character of the deposits changes abruptly from place to place and there is local channeling of the surface of the soft Morrison deposits, the erosion of these deposits appears to have been remarkably small—no more than would be expected from currents so strong as those which carried the coarse Cloverly deposits. It is therefore believed that no great interval of uplift and erosion followed Morrison deposition, for if such interval had occurred the soft deposits would have been widely removed. The coarse deposits of the Cloverly formation were derived from sources not clearly located and were spread by currents over a wide area. The coarse-grained lower member, generally 50 to 60 feet thick, gives place to a medial member of clay, mostly of purplish color, not unlike the Morrison beds. This is believed to represent the Fuson shale of the Black Hills and to be equivalent to part of the Comanche series. The top sandstone, resembling the Dakota sandstone of other regions, indicates a renewal of the strong currents which deposited the sands of the basal member of the formation.

After the deposition of the great sheets of sandy sediment that constitute the Cloverly formation there was a rapid change to clay deposition, of which the first representative is the widespread Benton shale. The deposition of this shale marks the beginning of the period of wide later Cretaceous submergence in which marine conditions prevailed in this region—a submergence that continued until several thousand feet of clay were deposited, during the Benton, Niobrara, and Pierre epochs. In Benton time some thin sheets of sand were laid down, one of which, in the later part of the epoch, extended over the greater portion of the northern Rocky Mountain region. Another marked episode was that which resulted in the deposition of the thin Greenhorn limestone in the middle of the Benton sediments along the east front of the Rocky Mountains from the Black Hills to New Mexico and far eastward. The formation of the Benton shale was followed by the deposition of several hundred feet of impure chalk, now constituting the Niobrara, and this in turn by the formation of the thick mass of the Pierre shale, which was deposited under very uniform conditions. The retreat of the late Cretaceous sea began in the later Montana or Fox Hills epoch, when a widespread mantle of sand was laid on the great series of clays. With further retreat of the sea extensive land surfaces were exposed, diversified by streams, lakes, and estuaries of brackish or fresh water, which received the sands, clays, and marsh deposits at the end of the Cretaceous period. Marine conditions recurred locally in later Montana time, as is shown by the appearance of characteristic marine fauna in shales overlying the earliest coal measures. Whether or not the late Cretaceous sediments were deposited over the area that is now occupied by the Laramie Mountains is not definitely known, but they probably were, for they are upturned along both sides of the uplift and do not become coarser toward the mountains.

Early Tertiary mountain growth.—That there was extensive uplift in the Rocky Mountain province in or just before early Tertiary time is clearly indicated in most of the mountain regions by the presence of Eocene and Oligocene deposits on eroded surfaces having the general outlines of the present topography. A very great amount of material was eroded from the higher part of the uplift, and although a portion of it is represented by various early Tertiary formations much has disappeared. Broad areas were worn lower at this time, and it is believed that the old plain on top of the Laramie Mountains was formed early in the Tertiary age and has since been considerably uplifted. It is probable that there was some deposition in the Laramie Basin and the plains to the east in early Eocene time, but if so the deposits were removed prior to Oligocene time, so that the local conditions during earliest Tertiary time are not known.

Oligocene to Pliocene deposition.—In late Tertiary time, after the outlines of the great mountain ranges had been developed, there was a long period in which rivers of moderate declivity flowed across the Great Plains region and through many of the wider valleys between the mountains. These streams, which flowed in varying channels and were interrupted by extensive local lakes due to damming and the sluggish flow of the water, laid down the widespread mantle of White River deposits, of Oligocene age. The first of these were the sands of the Chadron formation, which now occur partly as coarse sandstone, filling channels that show clearly the courses of old currents. Later, in slack waters and areas of overflow, fine sands, clays, and fuller's earth were deposited. Some thin but very widespread sheets of limestone at or near the top of this formation indicate the presence of extensive fresh-water ponds.

The Brule clay, which follows the Chadron, indicates a continuation of stream deposition, but with currents less strong and with extensive local lakes and slack-water overflows. The almost general fine-grained character of the sediments indicates that stream gradients either were low or rapidly became low in the area now occupied by the Brule clay.

At the beginning of Miocene time the general conditions had not materially changed, but the power of the great silt-depositing streams was increased, either by a climatic change or by a general uplift. They first eroded the surface of the Brule clay and other earlier formations and then deposited upon them a sheet of sands, beginning with many local deposits of coarse gravel and bowlders, especially near the mountains. This is the Arikaree formation. It was spread widely over the central plains region and in some areas attained a thickness of nearly a thousand feet, forming a flat alluvial fan of great extent. It extended far up the east slopes of the Laramie Mountains and buried some of the lower ridges.

This time was followed by a long epoch of erosion, which in the Laramie-Sherman region continued through the remainder of the Tertiary and during which some of the erosion products were carried away by streams and spread over portions of the country lying farther east and south.

Quaternary conditions.—At the beginning of Quaternary time all the broader topographic features of to-day had been outlined and largely developed, though the streams had not cut their valleys so deep and the wide plains of Tertiary deposits were much more extensive. During the glacial epoch there were glaciers of moderate size on parts of the Medicine Bow Range, but no trace of their presence has been found on the Laramie Mountains. As Quaternary time progressed the streams gradually deepened their valleys and left wide but thin bodies of alluvial deposits at different elevations. Where the streams have cut to lower levels the earlier deposits remain as terraces of various heights. These deposits form a minor feature on the east side of the Laramie Mountains, where the streams were small, but two erosion stages are clearly marked by elevated terrace remnants and the present alluvial flood plain.

The remarkable hollows in the Laramie Basin, such as Big Basin and the Big Hollow, have been developing for a long time. Apparently they began as slight hollows in the terrace and alluvial deposits and have been deepened by wind erosion. The precise conditions of their development are difficult to understand, as a vast volume of clay and sand has been removed from them; the amount removed from Big Hollow was more than 10,000,000,000 tons.

ECONOMIC GEOLOGY.

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

MINERAL RESOURCES.

There are numerous valuable mineral deposits in the quadrangles. Among the metalliferous minerals are ores of copper and gold; among the nonmetalliferous products are gypsum, bentonite, sulphate of soda, volcanic ash, cement, sand, clay, and limestone.

GYPSUM.

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

Rock gypsum.—The thickest deposits of gypsum rock in the Laramie Basin are 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 state boundary. The gypsum outcrop appears from beneath the Tertiary deposits near the middle of the west side of sec. 7 and, winding in and out around the foothills of Red Mountain through secs. 8, 9, and 10, passes out of the northwest corner of sec. 10. It then bends to the north, swings sharply west 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 throughout this region lies on a bed of Forelle limestone a foot or more thick that is full of fossils of upper Carboniferous age. A section of the gypsum-bearing beds measured at their maximum development in this vicinity, taken from the top of the beds on the north foot of Red Mountain, in sec. 9, down to the fossil bed, is as follows:

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

	Feet.
Red gypsum, 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.

A small pit a mile east of Sportsman Lake, near the middle of the north side of sec. 7, T. 13 N., R. 73 W., shows 4 or 5 feet of pure rock gypsum, but whether this is the full thickness of the bed is not known. A curly, laminated gypsiferous limestone outcrops a quarter of a mile farther east and dips beneath the gypsum. This limestone rises as a long ridge extending east of north to Forelle and beyond. It passes 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 a deposit of gypsum which has been worked since 1890 by the Consolidated Plaster Company. The beds here 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, northwest of the mill, 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 switch 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 by D. O'Brien, Colorado Agricultural College, of the gypsum from this bed is as follows:

Analysis of gypsum from Red Buttes, Wyoming.

CaO	32.5
Al_2O_3	.3
FeO	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 which enters that section near the middle of its south side. 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 rock gypsum, are found 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 the greater part of sec. 4, T. 16 N., R. 73 W., and has a depth of 9 feet where worked. The first 7 feet is pure gypsite, which lies on a 5-inch red layer that is underlain by a foot or more of white gypsite resting on 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. The product, which amounts to 2500 tons a year, has the following composition:

Analysis of plaster of Acme Cement Plaster Company, Laramie, Wyo.

Lime (CaO)	37.11
Magnesia (MgO)	1.45
Sulphuric acid (SO_3)	43.37
Water (H_2O)	6.93
Alumina (Al_2O_3)	.59
Silica and insoluble matter (SiO_2)	5.50
Carbonic acid (CO_2) (by difference)	5.05
	100.00

Other smaller deposits near 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 extending along Soldier Creek for 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., 1 mile southeast of Red Buttes, and another one is worked by the Consolidated Plaster Company at Red Buttes. This deposit 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 thence extends 2 miles down Fivemile Creek. Another gypsite deposit underlies portions of secs. 33 and 34, T. 14 N., R. 74 W.

Many of the gypsite beds above mentioned have been carefully bored and tested by persons interested in their location, and others have been discovered by their effect on the vegetation growing over them. They are all shown on the areal geology sheet.

BENTONITE.

Occurrence.—The variety of clay known as bentonite occurs at many localities in Wyoming, usually as a bed in the lower portion of the Benton shale. In the Laramie Basin it occurs near the beds known as the Mowry shale member, usually above them, and is overlain by 20 feet of very dark shale containing concretions. At some localities it attains a thickness of 4 feet, but it is generally thinner and in places is only a few inches thick.

Character.—Freshly exposed bentonite ranges 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 with conchoidal fracture in blocks varying from those of roughly rectangular shape to long, slender prisms. The joints are more or less open and in places contain crystals and plates of gypsum and sulphate of soda. In texture bentonite is very fine grained, containing no grit that is perceptible to the touch and very little that can be felt 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 which are interspersed some 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 of the ground, which in many places resembles hoar frost. When this froth dries it becomes a soft white powder. Mixed with the proper amount of water bentonite becomes exceedingly plastic and with the addition of more water it forms 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 can be absorbed by diatomaceous earth.

Composition.—Bentonite is one of the kaolin group of hydrous silicates of alumina. Its resemblance to ehrenbergite has been pointed out by Knight, but Read considers it a variety of montmorillonite.

Uses.—The shipment of bentonite from the vicinity of Rock Creek began in 1888, when several carloads were used by eastern firms in the manufacture of packing or dressing for the inflamed hoofs of horses. Its chief use, however, is to give body and weight to paper, and practically the whole output of the clay for the last few years has been taken by a paper mill in Denver, Colo. It has been used also in antiphlogistine, a proprietary remedial dressing, and as an adulterant of candies and drugs. Though highly plastic it is unsuitable for the manufacture of burnt-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 that of diatomaceous earth suggests its substitution for that material in the manufacture of dynamite.

Creighton Lake.—Along the bluff on the northwest shore of Creighton Lake, 6 miles west of Red Buttes, a bed of bentonite appears as a white band in the black shale of the Benton formation, extending for a distance of 200 yards. This bed is 3 to 4 feet thick, dips about 5° west-southwest, and lies a short distance above the Mowry shale member, which outcrops to the east. Apparently the quality of the clay 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 on 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 member is not clear but probably it lies beneath the shale.

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 averaged about 60 tons annually. From that time it gradually increased until in 1902 it was reported to have been 1200 tons. 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 a ton f. o. b. The price then dropped to $5 a ton but later rose to $6 and $7 a ton. The total production to 1905 was about 6000 tons, having an aggregate value of $45,000.

SULPHATE OF SODA.

The Laramie Basin contains three deposits of sulphate of soda in the bottoms of small lake basins. These are 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 north of old Rock Creek station. These lakes 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 Union Pacific Soda Lakes cover an area of 60 acres in the N. ½ sec. 4, T. 14 N., R. 75 W. The deposit in these ponds is said to be more than 12 feet thick and an 8-foot cube of the soda was once taken out. Twenty years ago the deposits were worked to some extent and the product was carried by a branch railroad to Laramie. For a time it was converted into caustic soda and sodium carbonate, but the industry was not profitable, owing, it is stated, to inefficient methods. Later the soda was utilized in a glass furnace at Laramie, but there has been no production from these ponds since 1895. After the Pioneer ditch was dug the ponds were filled and enlarged by seepage, but doubtless the soda still remains on the bottom. Originally the waters had specific gravities ranging from 1.048 to 1.088 and contained the following constituents:

Mineral content of waters of Union Pacific Soda Lakes, in grams per liter (parts per thousand).[a]

	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	1.46	1.21	.75
	55.14	82.00	101.42

[a]Reported by Pemberton and Tucker, Chemical News, vol. 68, p. 19. The last item, which was given as sodium borate, is probably sodium carbonate.

Analyses of an average sample of the deposit gave the following results:

Analysis of deposits in Union Pacific Soda Lakes.

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 the cleanest material contained 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 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 is several inches thick. The northern lake is the lowest and smallest, but its salts are purer, containing less mud. An analysis of clean crystals from its surface made by E. E. Slosson gave over 95 per cent of hydrous sodium sulphate. The southern lake is slightly higher than the middle one but it contains water and is very 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 small amounts of sodium chloride and sodium carbonate. The specific gravity is 1.261.

The following are Slosson's analyses of the waters and salts collected by him or by W. C. Knight, in 1899 and 1901.

Analyses of soda deposits from the Downey Lakes, Albany County, Wyo.[a]

	162.	163.	173.	175.	176.	178.	182.
Hypothetical combination:							
Water	44.41	74.60	75.89	49.29	72.79	55.43	55.94
Insoluble	.11	------	.02	.51	.13	2.24	.10
Sodium sulphate (Na_2SO_4)	28.24	6.93	11.50	19.67	12.77	39.17	41.02
Sodium chloride (NaCl)	.28	1.16	.45	.50	.86	.12	.12
Magnesium sulphate ($MgSO_4$)	26.96	17.31	12.08	30.03	13.40	2.24	1.82
Sodium carbonate (Na_2CO_3)	------	------	.06	------	.05	------	------
Calcium sulphate ($CaSO_4$)	------	------	------	------	------	.80	------
Calculated as dry salts:							
Sodium sulphate (Na_2SO_4)	50.90	25.61	47.74	39.18	47.18	92.54	95.46
Sodium chloride (NaCl)	.50	5.28	1.86	1.00	3.17	.28	.28
Magnesium sulphate ($MgSO_4$)	48.60	70.11	50.16	59.82	49.47	5.29	4.26
Sodium carbonate (Na_2CO_3)	------	------	.24	------	.18	------	------
Calcium sulphate ($CaSO_4$)	------	------	------	------	------	1.89	------

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

Samples numbered 162 and 163 were collected in 1899; the other samples were collected in 1901.

162. Crystallized salts from under water in the middle lake.
163. Solution standing above the salts represented by No. 162.
173. Water from southern lake.
175. Crystallized salts found in a small ditch leading out of southern lake.
176. Solution that filled in the blast hole when No. 178 was taken.
178. Large, clear crystals of mirabilite mixed with mud and water, obtained from middle lake by blasting through the crust to the depth of about 6 feet near the middle of the lake.
182. Sample of purest crystals obtainable from the extreme north end of northern lake.

Professor Knight reported tests at the Downey Lakes, where several holes were sunk through the deposit. In the course of a few hours these holes were filled with a saturated solution of sulphate of soda, indicating a rate of flow of 450 gallons an hour. The solution was supersaturated and had a gravity of 31° Baumé, containing slightly more than 75 per cent of hydrous sodium sulphate. At this rate $2\frac{1}{2}$ tons of the anhydrous salt would be obtained every twenty-four hours if the influx of water into the pits were 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.

VOLCANIC ASH.

A deposit of volcanic ash is exposed on the southern end of a low mesa in the NW. $\frac{1}{4}$ 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 dust. 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)	5.0
Water (by difference)	8.2
	100

The upper bed has been opened in two or three places within a distance of 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, but no evidence is presented to indicate in which system it belongs.

COAL.

The sandstones of the upper division of the Montana group carry coal in the northern portion of the Laramie Basin, but no workable bed has yet been discovered in the Laramie quadrangle. Some coal of good quality has been mined at a point about 2 miles due west of Webbs Lake, from a bed about 4 feet thick. It is possible that this bed extends into the western part of the Laramie quadrangle, in Mill Creek valley or the slopes farther north, but owing to the covering of Quaternary deposits this was not determined.

Excavations for coal have been made in the Benton and other shales at various localities, with negative results. The most extensive openings are in shales in the Cloverly formation a mile west of Bona. There are no prospects of finding coal in this region in any of the formations below the sandstones of the Montana group.

CEMENT ROCK.

Materials for the manufacture of cement exist in large amount in the Laramie Basin, but they have not yet been utilized. One of the most promising rocks is the impure limestone of the Niobrara formation, which is widely distributed. In places it consists of a mixture of 75 per cent of carbonate of lime and 25 per cent of clays, which is about the usual proportion for cement. The limestones of the Casper, Forelle, Chugwater, Morrison, and Arikaree formations could also be mixed with the 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 region. Sand for the glass works formerly in operation at Laramie was obtained from very soft sandstone of the Casper formation at a point 3 miles east of the city. The material was nearly pure silica, containing only a slight trace of iron and a small amount of carbonaceous matter.

CLAY.

The alluvial deposits consist partly of clay, especially in the wide portions of the valleys of Laramie and Little Laramie rivers, and the Morrison and Benton formations and the lower part of the Montana group consist mainly of clay. The Chugwater formation contains much red sandy clay. Bricks have been made from the alluvial clays at some places and for the last few years a brick plant not far west of Laramie has 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 has been used in several buildings in Laramie, including the Carnegie Library. It stands a pressure of 5400 pounds to the square inch.

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 could 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 appears to be good. Limestone occurs also in the Morrison formation in beds ranging in thickness from 6 inches to 2 feet, but its quality has not been tested. The top limestone of the Casper formation has been worked to some extent 2 miles east of Laramie, in a quarry which is 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 (analyst unknown) has been published:

Analysis of limestone quarried 2 miles east of Laramie, Wyo.

Calcium carbonate	98.83
Magnesium carbonate	.45
Iron carbonate	.02
Iron bisulphide	.10
Alumina	.43
Silica	.05

The limestone included in the Arikaree formation in the southeast corner of the Sherman quadrangle is in greater part of notable purity. An analysis by Chase Palmer in the laboratory of the United States Geological Survey gave 97.65 per cent of carbonate of lime, 0.17 per cent of magnesia and 0.61 per cent of insoluble matter.

The calcareous sediments of the Niobrara limestone contain considerable clay admixture. One typical sample from a place west of Laramie contained only 71 per cent of carbonate of lime.

GRAVEL.

The long-continued decay of the coarse-grained Sherman granite has produced vast quantities of residual gravel, which mantle the surface in the more open and level parts of the pre-Cambrian area. Large amounts of this have been quarried and used as railroad ballast and road metal and in gravel walks. At Buford station the Union Pacific Railroad has been excavating this gravel for use as ballast, and has graded its track with it for hundreds of miles both east and west of this station. In the decay of the granite the micas and hornblendes are decomposed, leaving the large crystals of feldspar, more or less cemented together by quartz, in the form of coarse angular gravel. With the help of a little blasting to loosen the material, it can be readily excavated by steam shovels to a depth of 40 feet. At many other localities on the open plateau surface similar gravel beds may be utilized.

BUILDING STONE.

In most parts of the district the pre-Cambrian rocks are too deeply weathered at the surface to afford sound stone, and the expense of excavating down to the more solid portion would be considerable. This statement applies particularly to the Sherman granite. There are, however, some places in the northwest part of the Sherman quadrangle where the gray anorthosite is sufficiently firm and undecayed to be used as building material. The rock is clear gray in color, with more or less speckling of black, and when polished would doubtless prove to be a handsome ornamental stone, but it lies so far from the railroad that it is not yet available for use except in the immediate neighborhood in which it is exposed.

Some of the limestones and sandstones of the various formations are suitable for building stone, but on account of the slight local demand and the expense of shipment to distant markets they have not yet been utilized. The most valuable are probably the red sandstones of the Casper formation, which are of good color and satisfactory texture and occur in large bodies that may be easily quarried.

COPPER.

Copper minerals occur at many places in the granites and associated rocks of the Laramie Mountains and the spurs of the Medicine Bow Range. The only notable developments, however, have been at the Strong mines near Leslie and in the Silver Crown mining district west of Hecla. At Hecla a smelter was erected and considerable ore was produced, but the results were apparently unsatisfactory, as the works are now abandoned. The Strong mine consists of a shaft 360 feet deep. The principal deposits appear to be in the intrusive diorite.

BISMUTH.

A small vein of bismuth carbonate has been discovered near the schist-granite contact on the south end of Jelm Mountain. The claim is in sec. 24, T. 13 N., R. 77 W. A 200-foot shaft has been sunk and small samples of rich mineral have been obtained, but the exploration has not disclosed any satisfactory body of ore.

UNDERGROUND WATERS.

GENERAL CONDITION.

The succession and the structure of the rocks in the Laramie Basin are favorable to the occurrence of large supplies of underground waters, which are obtainable by wells sunk to different depths. There are water-bearing sandstones in the Casper, Cloverly, Benton, and Mesaverde formations, and water occurs also in the Chugwater red beds, the Tertiary deposits, the alluvium, and the higher terrace deposits. As shown in the structure sections and columnar section, most of the sandstones are widely extended sheets of considerable thickness interbedded among relatively impervious shales, the structure thus producing conditions especially favorable for underground water storage. Most of the sandstones outcrop at high levels and their dip toward the center of the basin carries them to considerable depth under areas of lower altitude. As they are overlain by relatively impervious shales, their contained water is under considerable head or pressure. Some of the sandstones, notably those of the Casper formation, lie very deep near the center of the basin, but in this portion of the area water-bearing sandstones of higher horizons are within reach of borings of ordinary depth. The underground waters have been extensively developed only in the vicinity of Laramie, where numerous flowing wells obtain supplies, most of them from the sandstones in the upper portions of the Casper formation. In most other portions of the region surface waters are used or water is obtained by shallow wells that derive supplies from the alluvium. The sandstone of the Cloverly formation, which is a useful source of supply in other regions, has not been greatly drawn upon in the Laramie Basin, but a boring for oil near Hutton Lake has shown that the formation contains water, although it was not under sufficient pressure at that place to afford a flow. The sandstone near the top of the Benton shale is not very thick, but it is porous and persistent, so that it may confidently be expected to furnish water. The sandstones constituting a large part of the upper division of the Montana group contain large amounts of water, which, no doubt, is under sufficient pressure to afford flows in some parts of the lower lands.

Deep borings and wells in Albany County, Wyo.

Owner.	Location.	Depth (feet).	Yield (gallons per minute).
S. W. Downey	SW. cor. sec. 4, half a mile south of Laramie.	201?	2½[a]
Do	Sec. 1 or 12, T. 18, R. 78	380	Many.[a]
O. D. Downey	Sec. 4, T. 15, R. 73	170	5[a]
Do	Do	531	10
Plaster Company	Laramie	952	25[a]
Oxford ranch	Red Buttes	540	Small flow.[a]
Thomas McHugh	NE. ¼ sec. 5, T. 15, R. 73	112	1[a]
Do	NE. ¼ sec. 8, T. 15, R. 73	117	1[a]
U. P. R. R. sheep pasture	Sec. 27, T. 16, R. 73, 2 miles northeast of Laramie.	1001	20[a]
J. Simpson	NE. ¼ sec. 5, T. 15, R. 73	112	½[a]
Downie ranch	3 miles west of Laramie	400	
G. H. Hunt	Sec. 10, T. 15, R. 73	220	Many.
G. Montague		150	Small flows.[a]
Paul Pascoe ranch	Mud Springs		Flows.
Ryan Brothers		85	½[a]
University	Laramie	1015	34[a]
Penitentiary	West of Laramie	?	
County	Laramie	1500	Many.[a]
Cemetery	Laramie	1003	4[a]
Judson ranch	Sec. 23, T. 19, R. 77	540	5[b]
Experimental farm	Laramie		
Mantell ranch			Temp. flow.
George ranch (6 wells)	West of Laramie	120–312	Few.[a]
Pelton ranch	SW. cor. sec. 10, T. 15, R. 73.	333	Few.[a]
Bacon ranch (3 wells)			Few.
Bell ranch (Millbrook)	Sec. 8, T. 16, R. 76		
J. S. Braskett	Downey addition, Laramie	100–125	Few.[a]
Harpers		450	Pumps from —225 feet.[c]
Homer ranch	Sec. 12, T. 14, R. 74	1118	Pumps from —4 feet.
Hospital	Laramie	200 or less	([d])
Alsop ranch	Sec. 34, T. 17, R. 75	300	Pumps.
Corthell & Bevans	One-eighth mile north of cemetery.	313	Small flow.
Haley ranch	Near Wyoming station	89	—18 inches.
Sherrod addition	Laramie	189	Failure.
Trabing ranch	SE. ¼ sec. 25, T. 25, R. 74	?	Flowed originally.
Sartoris Willan home ranch	Branch of Little Laramie River.	500	—4 feet.
Mansfield ranch	NE. ¼ sec. 20, T. 14, R. 75	502	([e])
"Oil well"	NW. ¼ sec. 13, T. 14, R. 75	1700	Flow.

[a] Good water. [b] Sulphur water, poor. [c] Corrosive and foams.
[d] Flowed at first but now 40 feet below surface. [e] Salt water.

In the Sherman quadrangle the dip of the older sedimentary rocks is so steep that the prospect of obtaining underground water from them is generally unfavorable. The water supplies of the quadrangle are derived chiefly from shallow wells in the alluvium or in the Tertiary deposits. Doubtless deeper wells in the valleys would reach the sandstones of the Montana group, which may yield flows, as they have in wells about Islay and northwest of Cheyenne.

FLOWING WELLS NEAR LARAMIE.

Numerous artesian wells in and near Laramie yield abundant supplies of water of excellent quality. They range in depth from 120 to 1500 feet. The deeper wells draw their supply from the upper part of the Casper formation, from sandstones which outcrop on the mountain slopes a short distance east of the city. Others obtain water from sandy portions of the overlying red beds.

The most notable well in Laramie is at the State University. This was sunk about ten years ago, to a depth of 1015 feet, and obtained a flow of soft water of 34 gallons a minute, reported to come mainly from a depth of 987 to 990 feet. The following description of the borings from this well has been compiled from various sources:

Notes on borings from University well at Laramie, Wyo.

	Depth (feet).
Gravel, sand, and red loam	40
Red sandy clay with scattered 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	1015

From depths of 80 to 150 feet the materials are coarse; from 150 to 300 feet they are finer grained and brownish red; from 300 to 560 feet the material is much lighter colored and finer and contains some carbonate of lime; from 560 to 590 feet it is mottled, coarser, darker, with a little carbonate of lime; from 590 to 615 feet it contains coarse fragments of red sandstone and gypsum; from 615 to 650 feet it is coarse-grained brown sandstone, with no gypsum; from 650 to 680 feet it is coarse sand with some gypsum; from 690 to 780 feet it is medium coarse grained brown sandstone; from 780 to 880 feet it is sandstone, very much lighter colored and very fine; from 880 to 960 feet it is almost white, very fine sand and carbonate of lime; from 960 to 1015 feet it is a little coarser than the last and has about the same amount of carbonate of lime, but is cream colored.

There are 40 feet of 7⅝-inch casing in the well to shut off gravel at the top, and 600 feet of 5⅝-inch casing. The first flow, obtained from a depth of 458 feet, comes up between the two casings; the second flow, from 820 feet, is apparently from the highest sandstone in the Casper formation; and the main flow began at 987 feet. Drilling was continued to a depth of 1015 feet, but no additional water was obtained below 990 feet. The amount of water flowing at the beginning was measured by B. C. Buffum and found to be 50,000 gallons a day of twenty-four hours. An analysis of the water is given on page 17. The well cost $2,552, including $552 for casing.

A well sunk 1500 feet by the county is in the SW. ¼ sec. 28, T. 16 N., R. 73 W., just across the road from the western one of the two small lakes in the northern part of Laramie. It encountered several flows but its main flow was obtained from a depth of 987 feet, in the top sandstone of Casper formation, and no water was found below this. The well flowed a solid 4-inch stream under sufficient pressure to jet 20 feet high through a 1-inch nozzle or, it is claimed, to rise over 60 feet above the surface. The well is cased with 835 feet of 6½-inch casing and 400 feet of 9-inch casing. Apparently no record of this boring is available but the following samples from 750 feet to the bottom (1500 feet) are preserved in the courthouse in Laramie:

Borings from county well, Laramie, Wyo.

Character of material.	Thickness.	Depth.
	Feet.	*Feet.*
Red fine-grained sandstone with some grains of white quartz, somewhat flaky	177	750– 927
Pure white sand. Main flow at 987 feet.	73	927–1000
White sand with enough red grains to give it a slight pink tint	15	1000–1015
Pure buff sand, with a few flakes of limestone (?)	15	1015–1030
Pure white limestone with a few grains of sand; nearly all dissolves in acid	60	1030–1090
Pinkish, granular; mostly sand, some limestone flakes. Contains much carbonate of lime in upper part	105	1090–1195
White flakes and chunks of limestone one-sixteenth to one-eighth inch in diameter. Dissolves in acid	5	1195–1200
"Marked highly magnetic lime rock below oil rock and above red sand rock." Chunks one-half inch long, of slightly purplish, very fine-grained limestone; effervesces strongly in cold acid. Does not affect the compass needle	15	1200–1215
"Marked soft red sandstone." Soft, fine-grained salmon-red powder; considerable fine grit. Shale, probably	10	1215–1225
Red sandstone, medium grains; coarser than the last	10	1225–1235
In part granular, reddish, more than half flat flakes of crystalline limestone. Dissolves completely in acid	10	1235–1245
Almost all pinkish fine-grained sand; some few flakes of limestone.	70	1245–1315
Almost pure pinkish fine-grained sand	10	1315–1325
Very fine reddish material, probably shale	30	1325–1355
Coarse fragments of quartz and feldspar up to one-sixteenth inch in diameter (arkose)	15	1355–1370
Coarse pinkish or reddish quartz sand	30	1370–1400
Perfectly rounded quartz grains, medium fine, one-half white, one-half deep red	15	1400–1415
Sand and chunks of rock consisting of sand grains in a limestone matrix. Dissolves partly in acid, leaving loose sand	25	1415–1440
Fine-grained reddish material, probably shale. Dissolves slowly and partly in acid	10	1440–1450
Pure white fine-grained sand; dissolves slightly in acid	6	1450–1456
Coarse quartz grains mixed with a fine powder, which is nearly altogether limestone	14	1456–1470
Fine-grained reddish-white and black flakes. The white is limestone and dissolves in acid. The black particles may have been abraded from the drill	30	1470–1500

At the works of the Acme Plaster Company, in the southeast part of Laramie, there is a 4½-inch artesian well with a 25-gallon flow of soft water per minute, derived from a depth of 945 feet, from the upper sandstone of the Casper formation. The well is 952 feet deep and is cased to 627 feet. Some water was found at 600 feet. The head is sufficient to raise the water 74 feet above the surface. The following record was supplied by J. J. McCutchen, the driller:

Record of Acme Plaster Company's well, Laramie, Wyo.

Character of material.	Thickness.	Depth.
	Feet.	*Feet.*
Red shale	40	0– 40
Red sandstone	260	40–300
Limestone (Forelle) and shale	100	300–400
Soft, red sandstone, with gypsum	227	400–627
(?)	63	627–690
First flow in red sandstone		690
(?)	210	690–900
Gray sandstone with water	52	900–952

On the ranch of Charles George, in sec. 3, T. 15, R. 83, and the next section north, in the eastern part of Laramie, there are six deep wells within a radius of one-fourth of a mile. One, which passed through 90 feet of limestone, found water in sand rock. The water now stands 18 inches below the top of the casing. Mr. George sank two wells on the north side of his ranch in 1888. One of them, in the fair grounds, is 120 feet deep. It passed through 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 the other well, which is just outside 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 entirely in red beds, the water level is about 2 feet below the top, except in the spring, when it flows. In the other well, which is 30 yards distant, 8 feet higher, and 312 feet deep to limestone, the water level is 6 feet below the top. 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. When the large flowing well just outside the fair grounds is closed the others usually flow.

There is a group of flowing wells in the southern part of Laramie. One is east of the road in the SW. ¼ NW. ¼ sec. 4, T. 15 N., R. 73 W. It is 5 inches in diameter and flows about 2 gallons a minute of good water having a temperature of 44½°. 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, from a depth of 112 feet. The water has a temperature of 45°, 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°. Its depth is stated to be "about 201 feet." The two wells of O. D. Downey, in the same section, 170 and 53 feet deep, yield 5-gallon and 10-gallon flows.

In the cemetery at Laramie a well 1003 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. No data could be obtained regarding 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.

OTHER WELLS.

Wells of the 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 data were furnished in 1904 to W. C. Knight by W. L. Paake, superintendent.

Record of Union Pacific Railroad well northeast of Laramie, Wyo.

Character of beds.	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	136	0– 136
Red sandstone	8	136– 144
Red shale rock	30	144– 174
Red sandstone	18	174– 192
Red shale	68	192– 260
Red sandstone	5	260– 265
Red shale rock	65	265– 330
Red sand rock	50	330– 380
Hard red sand rock	25	380– 405
Red shale	30	405– 435
Red sand rock	65	435– 500
Red shale	40	500– 540
Red sand rock	18	540– 558
Hard red sandstone	12	558– 570
Soft red sand rock	60	570– 630
Hard red sand rock	25	630– 653
Soft red sand rock	32	653– 685
Hard red sand rock	25	685– 710
Soft white sand rock (top sandstone of Casper?)	15	710– 725
Hard red sand rock	13	725– 738
Hard red shelly sand rock	3	738– 741
Soft sand rock	3	741– 744
Hard red sand rock	5	744– 749
Hard white sandstone	10	749– 759
Soft white sandstone	11	759– 770
Red shale rock	10	770– 780
Hard red sandstone	2	780– 782
White limestone	18	782– 800
Hard white sandstone	15	800– 815
Hard white limestone	20	815– 835
Hard white sandstone	12	835– 847
White limestone	24	847– 871
Red sandstone	14	871– 885
Red shale rock	6	885– 891
Hard red sandstone	51	891– 942
Red shale	4	942– 946
Red sandstone	31	946– 977
Hard white rock	13	977– 990
Red sandstone	11	990–1001

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

Pelton ranch.—On the ranch of Charles W. Pelton, in the SW. $\frac{1}{4}$ 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 is entirely in red beds. At a depth of 120 feet water was found which rose within 60 feet of the surface and when the well was sunk deeper the water level rose within 7 feet of the top. The boring ended in quicksand. The water is of good quality, as is shown by the analysis given in the table on this page, and is used for irrigating an acre of garden. The second well is 200 yards north of the first and is also entirely in red beds. Its 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. $\frac{1}{4}$ 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. Its depth is not reported. Probably its source of supply is in the red beds.

Downie ranch.—At the Downie ranch, which is 3 miles west of Laramie, a $5\frac{5}{8}$-inch well 400 feet deep pumps 200 gallons a minute. The main supply is obtained from a depth of 395 feet. 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, Wyo.

Character of beds.	Thickness.	Depth.
	Feet.	*Feet.*
Surface deposits	20	0– 20
Blue shale (Graneros)	160	20-180
Sand rock, gray, hard and soft (Cloverly, etc.)	220	180–400

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 division of the Montana group.

"*Oil well.*"—An unsuccessful 1700-foot boring for oil was made several years ago near Laramie River, at a point 3 miles west of Hutton Lake. It is in the NW. $\frac{1}{4}$ sec. 13, T. 14 N., R. 75 W., and 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, Wyo.

	Thickness.	Depth.
	Feet.	*Feet.*
Black shale (Benton)	600	600
Sand and shale (Cloverly)	200	600– 800
Sandy slate	400	800–1200
Red, caving sandstone	100	1200–1300
Red sandstone, harder	100	1300–1400
Red sandstone, much harder	100	1400–1500
Brown and red sandstone, hard	190	1500–1690
Hard sandstone, with pebbles	10	1690–1700

A small amount of water was noted at a depth of 90 feet. Water that occurred at a depth of 600 feet in white sandstone 20 feet thick 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, which was in 20 feet of brown sandstone at a depth of 1500 feet, flowed over the casing.

Mansfield ranch.—On the Mansfield ranch, which is in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ 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 the drill entered the dark shale of the Benton formation, which 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 to a depth of about 900 feet so as to enter the sandstone of the Cloverly, which doubtless would have yielded good water. However, to judge by the experience of the oil boring in sec. 13 of the same township, 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 1118 feet deep yields a fair supply of water, which rises within 4 feet of the surface. No record was furnished, but from the thickness of the strata in the slopes east of the well it is believed that if this boring had been continued to a depth of 1250 feet, or possibly 1300 feet, it would have penetrated the top sandstones of the Casper formation and obtained a flow.

Islay.—There are several flowing wells about Islay station, which yield a fairly large volume of good water. Their depths range from 150 to 300 feet and apparently their water is derived from the Fox Hills sandstone, which underlies the White River group at a moderate depth in Lodgepole Valley.

SPRINGS.

Springs occur at widely separated localities throughout the Laramie Basin, especially along the slopes at the foot of the Laramie Mountains. These springs are the sources of water for numerous ranches, many of which were located so as to include the springs.

A series of very large springs issue from the limestone at the foot of the Laramie Mountains east and south of Laramie. From one of these, situated in the SE. $\frac{1}{4}$ sec. 35, T. 16 N., R. 73 W., the city is supplied with fine water for drinking and for the irrigation of its lawns and gardens and its numerous trees. The water, which issues at a point that is 114 feet higher than the level of Laramie, is conducted into covered reservoirs and thence piped to the city. An analysis of this water, given in the table (No. 3), shows that it is somewhat hard, but this fault can be remedied by boiling or by the use of lime. 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 flows into Soldier Creek. It supplies the fish hatchery with an abundance of cool water that is favorable to the propagation of trout and other fish. There are springs at the J. Simpson ranch, $2\frac{1}{2}$ miles farther south, which also supply good water in large volume.

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 fills a large 4-inch pipe nearly full. McGibbons spring, in the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 29, T. 14 N., R. 73 W., supplies a large fish pond, the overflow from which forms a considerable addition to Willow Creek. Willow Spring, in sec. 15, T. 13 N., R. 73 W., rises in a grassy, willowy quagmire several acres in extent. Its total discharge is between one-half and one second-foot and the quality of its water is good. Rice Spring is situated in the S. $\frac{1}{2}$ sec. 26, T. 13 N., R. 75 W., flowing from the Chugwater formation, not far above the gypsum horizon. The water at the spring is good and is used for domestic and stock purposes. About half a mile below the spring the stream becomes so badly contaminated with gypsum that fish can not live in it, though they thrive near the spring. Water of notable purity is found in a spring on Ernest Davis's ranch, near Sheep Mountain. An analysis is given in the table 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 the water level is now several feet below the surface. A small lake that formerly existed in the NE. $\frac{1}{4}$ 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.

There are many springs in the Laramie Mountains. They issue from crevices or from decomposed portions of the rock and unite to form streams whose waters are of excellent quality, far better than that of the streams of the lowlands at the sides of the mountains. The supply for Cheyenne is obtained from a reservoir on Crow Creek.

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.

HYPOTHETICAL COMBINATION.

[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.

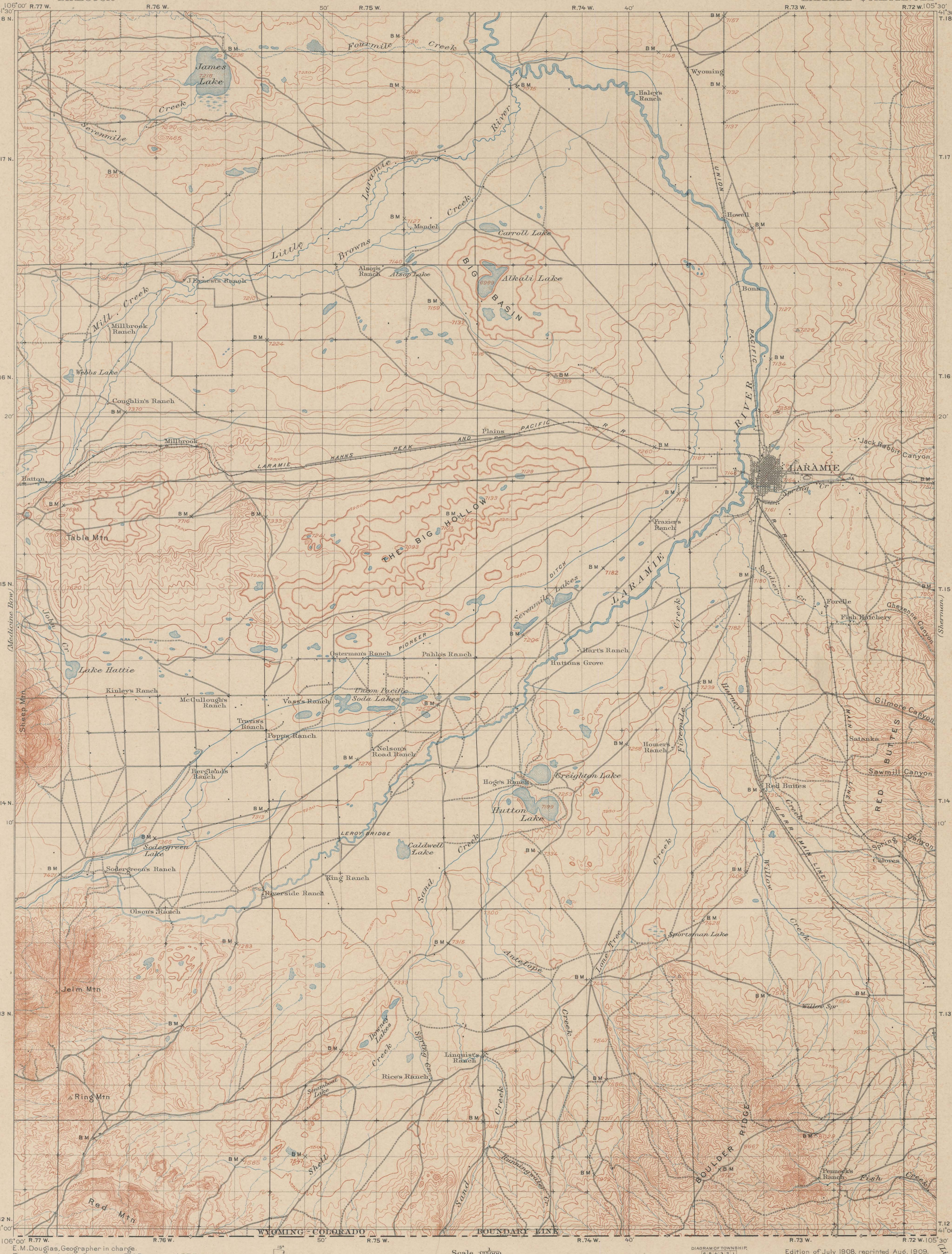
1. Davis Spring, near Sheep Mountain.
2. Pelton well, sec. 10, T. 15 N., R. 73 W.
3. Laramie Springs, 2 miles east of Laramie (city water), August 31, 1892.
4. University well, Laramie.
5. Fein well, $1\frac{1}{2}$ miles west of Laramie (58 feet deep; lithia water).
6. Laramie River, Pioneer canal at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

June, 1909.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH
DIRECTOR

TOPOGRAPHY

WYOMING
(ALBANY COUNTY)
LARAMIE QUADRANGLE



E.M. Douglas, Geographer in charge.
Topography by Wm. Stranahan, T.M. Bannon, and R.T. Evans.
Triangulation by Frank Tweedy and R.H. Chapman.
Surveyed in 1903 and 1906.

APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

Edition of July 1908, reprinted Aug. 1909.

LEGEND

RELIEF
printed in brown

Figures *showing heights above mean sea level instrumentally determined*

Contours *showing height above sea horizontal form, and steepness of slope of the surface*

Depression contours

DRAINAGE
printed in blue

Streams

Intermittent streams

Ditches

Lakes and ponds

Intermittent lakes

Marshes

CULTURE
printed in black

Roads and buildings

Churches, school houses, and cemeteries

Private and secondary roads

Trails

Railroads

Bridges

U.S. township and section lines

Located township and section corners

State lines and monuments

Triangulation stations

Bench marks

U.S. GEOLOGICAL SURVEY
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AREAL GEOLOGY

WYOMING
(ALBANY COUNTY)
LARAMIE QUADRANGLE

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TRUE NORTH — MAGNETIC NORTH — 15°
APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.
Edition of Sept. 1909.

DIAGRAM OF TOWNSHIP.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by N.H. Darton and C.E. Siebenthal.
Surveyed in 1905.

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles)

QUATERNARY

Recent

Qal — Alluvium *(only the larger areas shown)*

Qg — Gypsite deposits *(in alluvium)*

Pleistocene

Qt — Higher terrace deposits *(gravel and sand)*

TERTIARY

Tu — Undifferentiated Tertiary *(sand, gravel, and conglomerate)*

UNCONFORMITY

CRETACEOUS

Upper Cretaceous — *Montana group*

Kmv — Mesaverde formation *(soft, gray, massive sandstone with gray shale)*

Ks — Steele shale *(dark clay shale)*

Colorado group

Kn — Niobrara limestone *(impure chalky)*

Kb, Kmr — Benton shale *(gray shale with sandstone at top and Mowry hard shale member, Kmr, in lower part)*

Kc — Cloverly formation *(hard, massive, gray to brown sandstone with purple to gray shale in middle)*

CRETACEOUS OR JURASSIC

Km — Morrison formation *(massive, light greenish-gray to maroon shale and thin limestone)*

UNCONFORMITY

TRIASSIC OR PERMIAN

Ꞓc — Chugwater formation *(red sandstone and shale with thick beds of gypsum)*

CARBONIFEROUS

Pennsylvanian

Cf — Forelle limestone *(gray limestone in part gypsiferous)*

Cs — Satanka shale *(red sandy shale with local gypsum deposits)*

Cc — Casper formation *(red and gray sandstone and gray to purple limestone)*

IGNEOUS ROCKS

(Areas of igneous rocks are shown by patterns of triangles and rhombs; metamorphism is indicated by hachures)

PRE-CAMBRIAN

shg — Sherman granite *(coarse pink granite penetrated by numerous dikes)*

ob — Older basic intrusives *(dark diorite, gabbro, syenite, and granodiorite, some gneissic; only the larger masses shown)*

ggn — Granite gneiss *(coarse, grayish-pink, biotite gneiss, and fine, pink, muscovite gneiss)*

sgn — Schist and gneiss *(schistose basic and acidic lavas, with doubtfully sedimentary schists)*

Faults

10° Strike and dip of stratified rocks

Mines and quarries

x Prospects

U.S. GEOLOGICAL SURVEY
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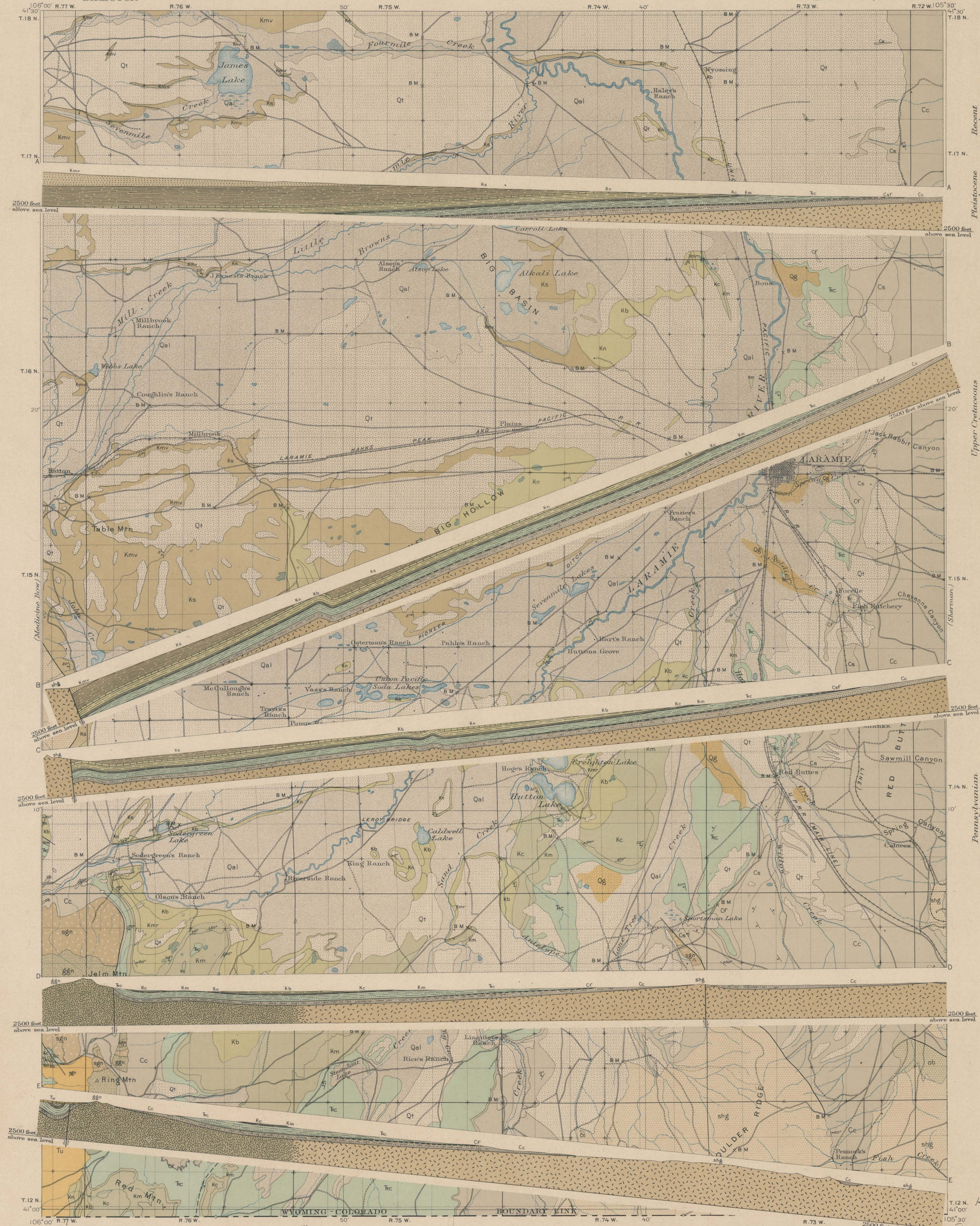
DIRECTOR

STRUCTURE SECTIONS

WYOMING
(ALBANY COUNTY)
LARAMIE QUADRANGLE



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APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

5 Miles

5 Kilometers

Edition of Sept. 1909.

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31	32	33	34	35	36

Geology by N. H. Darton and C. E. Siebenthal.
Surveyed in 1905.

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL — SECTION SYMBOL

QUATERNARY

Recent
- Qal — Alluvium (only the larger areas shown)
- Qg — Gypsite deposits (in alluvium)

Pleistocene
- Qt — Higher terrace deposits (gravel and sand)

TERTIARY
- Tu — Tu — Undifferentiated Tertiary (sand, gravel, and conglomerate)

UNCONFORMITY

CRETACEOUS

Upper Cretaceous — *Montana group*
- Kmv — Kmv — Mesaverde formation (soft, gray, massive sandstone with gray shale)
- Ks — Ks — Steele shale (dark clay shale)

Colorado group
- Kn — Kn — Niobrara limestone (impure chalky)
- Kb, Kmr — Kb — Benton shale (gray shale with sandstone at top and Mowry hard shale member, Kmr, in lower part)
- Kc — Kc — Cloverly formation (hard, massive, gray to brown sandstone with purple to gray shale in middle)

CRETACEOUS OR JURASSIC
- Km — Km — Morrison formation (massive, light greenish-gray to maroon shale and thin limestone)

UNCONFORMITY

TRIASSIC OR PERMIAN
- Trc — Trc — Chugwater formation (red sandstone and shale with thick beds of gypsum)

CARBONIFEROUS

Pennsylvanian
- Cf — Forelle limestone (gray limestone in part gypsiferous) — Combined with Satanka shale on sections A-A, B-B, and C-C
- Cs — Csf — Satanka shale (red sandy shale with local gypsum deposits)
- Cc — Cc — Casper formation (red and gray sandstone and gray to purple limestone)

IGNEOUS ROCKS

PRE-CAMBRIAN
- shg — shg — Sherman granite (coarse pink granite penetrated by numerous dikes; includes schists and other crystalline rocks on sections)
- ob — Older basic intrusives (dark diorite, gabbro, syenite, and granodiorite, some gneissic; only the larger masses shown)
- ggn — ggn — Granite gneiss (coarse, grayish-pink, biotite gneiss, and fine, pink, muscovite gneiss)
- sgn — Schist and gneiss (schistose basic and acidic lavas, with doubtfully sedimentary schists)

Faults

10° Strike and dip of stratified rocks

U.S. GEOLOGICAL SURVEY
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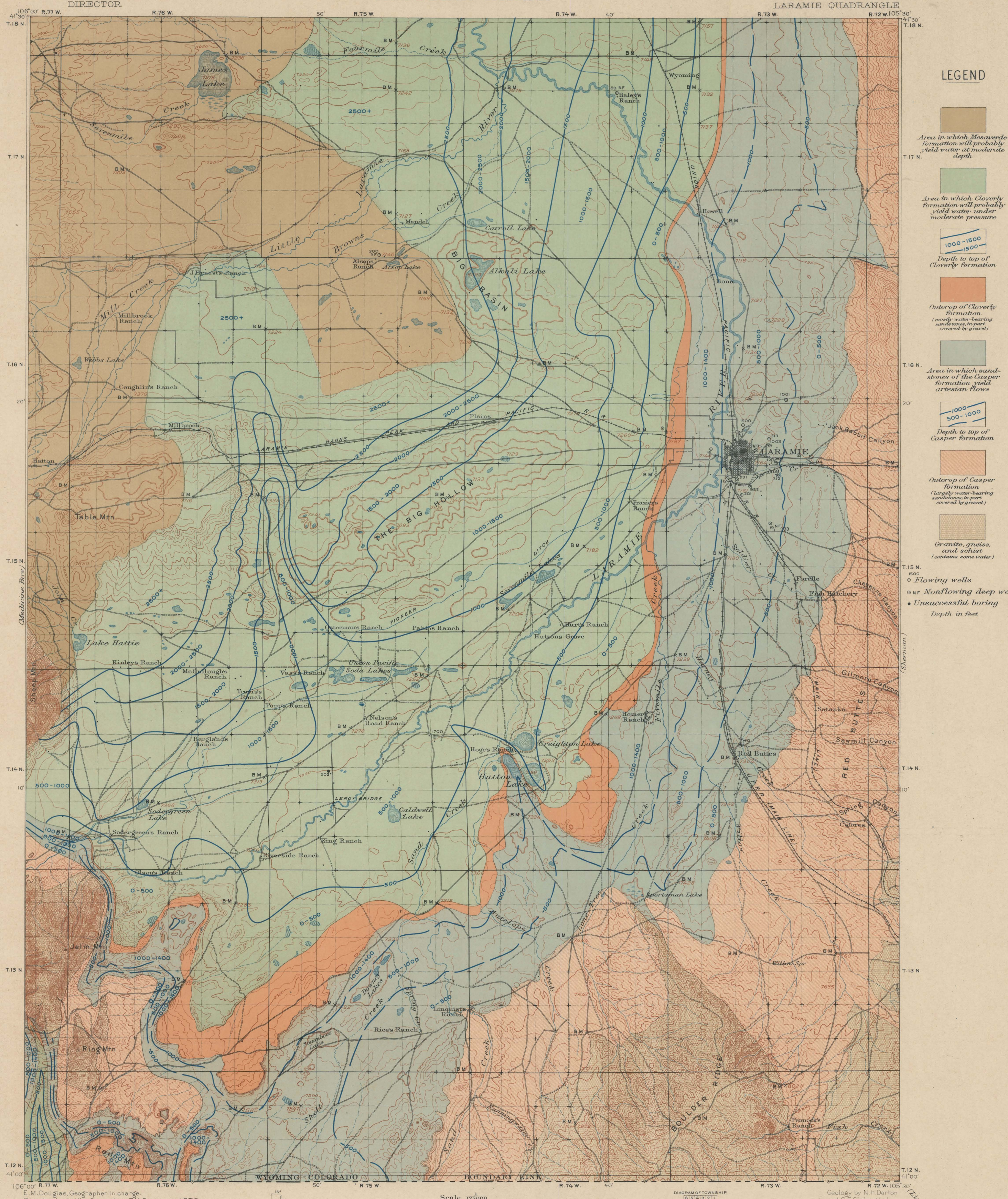
ARTESIAN WATER

WYOMING
(ALBANY COUNTY)
LARAMIE QUADRANGLE



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MAGNETIC NORTH
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Geology by N.H. Darton
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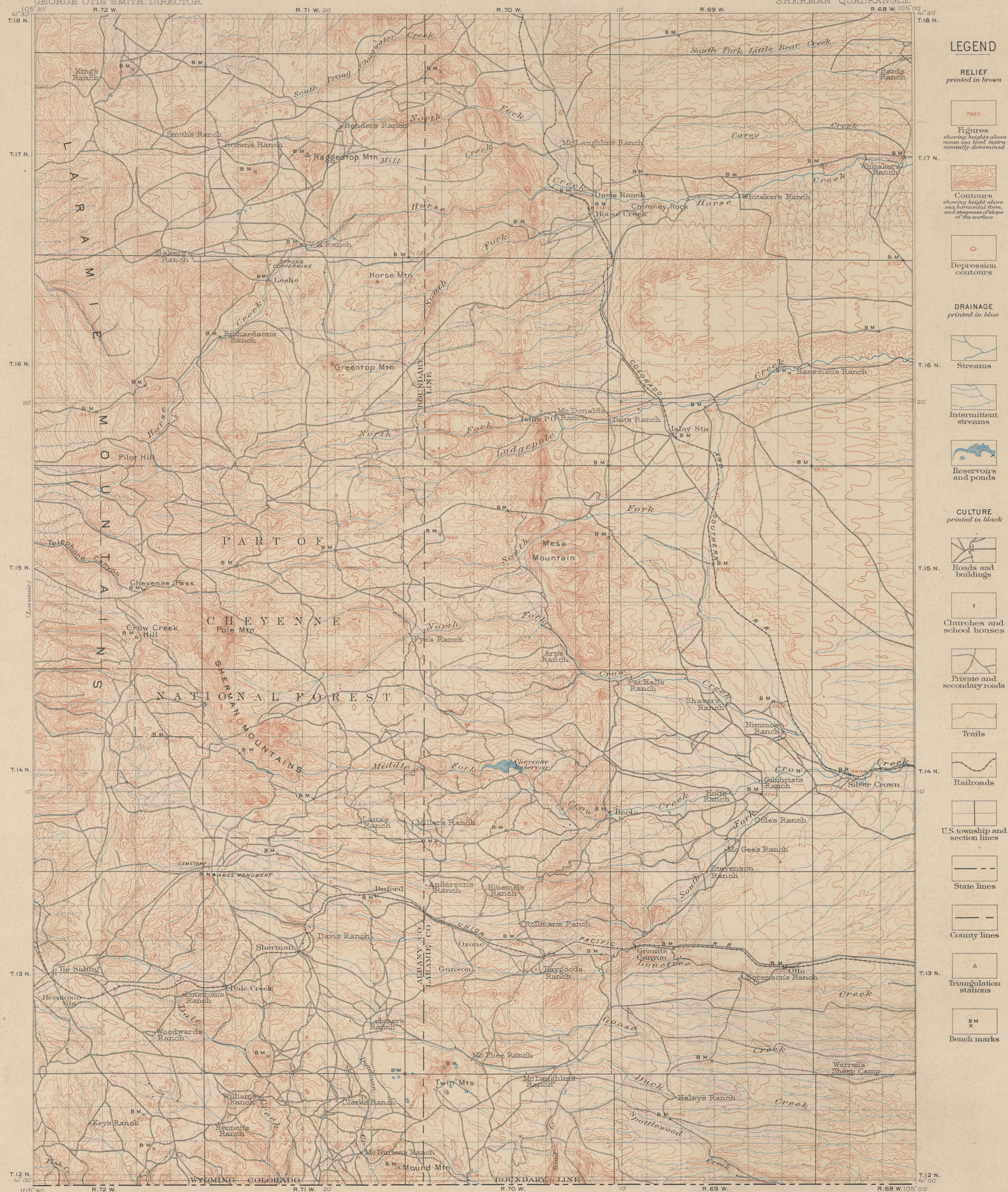
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

WYOMING
SHERMAN QUADRANGLE



E.M.Douglas, Geographer in charge.
Topography by T.M.Bannon.
Triangulation by R.H.Chapman.
Surveyed in 1903.

APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

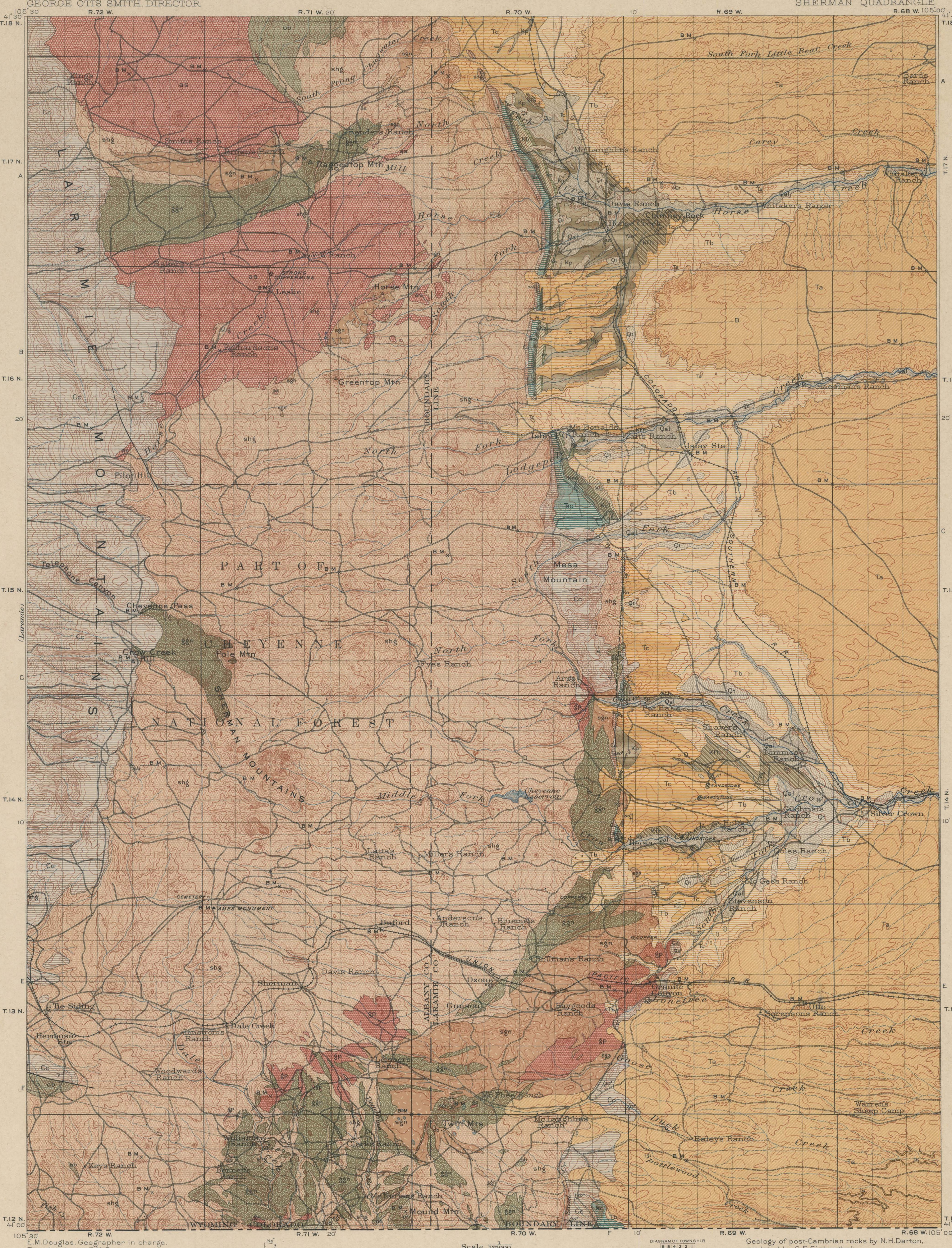
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Edition of Aug. 1905, reprinted Oct. 1909.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

AREAL GEOLOGY

WYOMING
SHERMAN QUADRANGLE



E.M.Douglas, Geographer in charge.
Topography by T.M.Bannon.
Triangulation by R.H.Chapman.
Surveyed in 1903.

TRUE NORTH
MAGNETIC NORTH
14½°
APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of Sept. 1909.

DIAGRAM OF TOWNSHIP

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Geology of post-Cambrian rocks by N.H.Darton,
assisted by C.E.Siebenthal.
Geology of pre-Cambrian rocks by Eliot Blackwelder.
Surveyed in 1905-1908.

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles)

QUATERNARY

Recent
- Qal — Alluvium *(only the larger areas shown)*

Pleistocene
- Qt — Higher terrace deposits *(not everywhere distinguishable from local products of disintegration)*

TERTIARY

Miocene
- Ta, ls — Arikaree formation *(sand, gravel, bowlders, coarse sandstone, and a lens of limestone, ls)*

UNCONFORMITY

Oligocene — White River group
- Tb — Brule clay *(mostly pale-buff, massive, hard, sandy clay)*
- Tc — Chadron sandstone *(mostly coarse, hard, brown, massive sandstone)*

UNCONFORMITY

CRETACEOUS

Upper Cretaceous — Montana group
- Kfh — Fox Hills sandstone *(soft, gray, massive sandstone with gray shale)*
- Kp — Pierre shale *(dark shale grading up into sandstone)*

Upper Cretaceous — Colorado group
- Kn — Niobrara limestone *(chalky and impure in upper portion)*
- Kb — Benton shale *(gray shale with concretions near top and sandstone in lower part)*
- Kc — Cloverly formation *(hard, massive, gray to brown sandstone with purple to gray shale in middle)*

CRETACEOUS OR JURASSIC
- Km — Morrison formation *(massive, light greenish-gray to maroon shale and thin limestone)*

JURASSIC
- Js — Sundance formation *(buff, slabby sandstone and gray, sandy shale)*

UNCONFORMITY

TRIASSIC OR PERMIAN?
- ℞c — Chugwater formation *(red, sandy shale and sandstone; with thin limestones and thick beds of gypsum)*

UNCONFORMITY?

CARBONIFEROUS

Pennsylvanian
- Cc — Casper formation *(limestone and red and gray sandstone)*

IGNEOUS ROCKS

(Areas of igneous rocks are shown by patterns of triangles and rhombs; metamorphism is indicated by hachures)

PRE-CAMBRIAN
- shg — Sherman granite *(coarse pink granite penetrated by numerous dikes)*
- as — Anorthosite *(gray anorthosite and diorite)*
- gp — Granite porphyry *(gray quartz-feldspar-hornblende porphyries)*
- ob — Older basic intrusives *(dark diorite, gabbro, syenite, and granodiorite, some gneissic; only the larger masses shown)*
- ggn — Granite gneiss *(coarse, grayish-pink, biotite gneiss, and fine, pink, muscovite gneiss)*
- sgn — Schist and gneiss *(schistose basic and acidic lavas, with doubtfully sedimentary schists)*

Faults

Concealed faults *(covered by later deposits)*

30° *Strike and dip of stratified rocks*

Strike of vertical strata

⚒ *Mines and quarries*

U.S. GEOLOGICAL SURVEY
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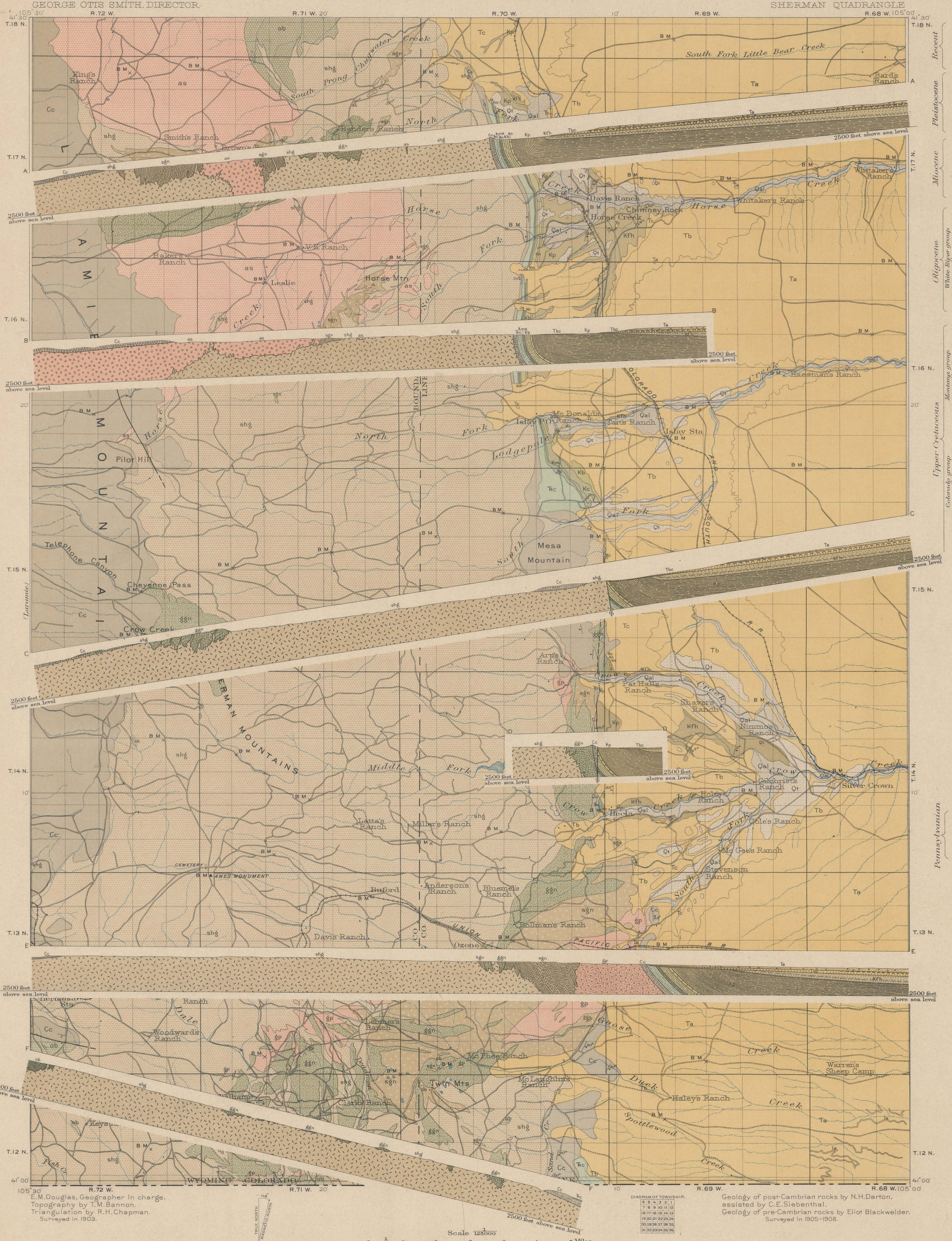
STRUCTURE SECTIONS

WYOMING
SHERMAN QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY

Recent

Qal — **Alluvium** (*only the larger areas shown*)

Pleistocene

Qt — **Higher terrace deposits** (*not everywhere distinguishable from local products of disintegration*)

TERTIARY

Miocene

Ta / Ta — **Arikaree formation** (*sand, gravel, bowlders, coarse sandstone, and a lens of limestone, ls*)

UNCONFORMITY

Oligocene — *White River group*

Tb / Tbc — **Brule clay** (*mostly pale-buff, massive, hard, sandy clay*)

Tc — Combined with Brule clay on sections — **Chadron sandstone** (*mostly coarse, hard, brown, massive sandstone*)

UNCONFORMITY

CRETACEOUS

Upper Cretaceous — *Montana group*

Kfh / Kfh — **Fox Hills sandstone** (*soft, gray, massive sandstone with gray shale*)

Kp / Kp — **Pierre shale** (*dark shale grading up into sandstone*)

Colorado group

Kn / Kn — **Niobrara limestone** (*chalky and impure in upper portion*)

Kb / Kb — **Benton shale** (*gray shale with concretions near top and sandstone in lower part*)

Kc / Kc — **Cloverly formation** (*hard, massive, gray to brown sandstone with purple to gray shale in middle*)

CRETACEOUS OR JURASSIC

Km / Kms — **Morrison formation** (*massive, light greenish-gray to maroon shale and thin limestone*)

JURASSIC

Js — Combined with Morrison formation on sections — **Sundance formation** (*buff, slabby sandstone and gray, sandy shale*)

UNCONFORMITY

TRIASSIC OR PERMIAN ?

Ꞧc / Ꞧc — **Chugwater formation** (*red, sandy shale and sandstone, with thin limestones and thick beds of gypsum*)

UNCONFORMITY ?

CARBONIFEROUS

Pennsylvanian

Cc / Cc — **Casper formation** (*limestone and red and gray sandstone*)

IGNEOUS ROCKS

PRE-CAMBRIAN

shg / shg — **Sherman granite** (*coarse pink granite penetrated by numerous dikes*)

as / as — **Anorthosite** (*gray anorthosite and diorite*)

gp / gp — **Granite porphyry** (*gray quartz-feldspar-hornblende porphyries*)

ob / ob — **Older basic intrusives** (*dark diorite, gabbro, syenite, and granodiorite, some gneissic; only the larger masses shown*)

ggn / ggn — **Granite gneiss** (*coarse, grayish-pink, biotite gneiss, and fine, pink, muscovite gneiss*)

sgn / sgn — **Schist and gneiss** (*schistose basic and acidic lavas, with doubtfully sedimentary schists*)

Faults

Concealed faults (*covered by later deposits*)

30° Strike and dip of stratified rocks

Strike of vertical strata

E.M. Douglas, Geographer in charge.
Topography by T.M. Bannon.
Triangulation by R.H. Chapman.
Surveyed in 1903.

APPROXIMATE MEAN DECLINATION 1903. TRUE NORTH. MAGNETIC NORTH. 14½°

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of Sept. 1909.

DIAGRAM OF TOWNSHIP.

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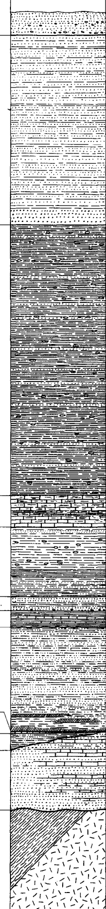
Geology of post-Cambrian rocks by N.H. Darton, assisted by C.E. Siebenthal.
Geology of pre-Cambrian rocks by Eliot Blackwelder.
Surveyed in 1905-1908.

COLUMNAR SECTIONS

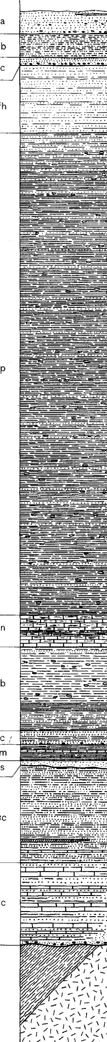
GENERALIZED SECTION FOR THE LARAMIE QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.

System.	Series.		Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
TERTIARY			Undifferentiated Tertiary. UNCONFORMITY	Tu		200–250	Sand, gravel, and bowlder beds.	Rolling plains. Good soil and pasture land.
CRETACEOUS	UPPER CRETACEOUS	MONTANA GROUP	Mesaverde formation.	Kmv		2000	Gray sandstone and sandy shale, with massive hard gray to buff sandstone at base.	Ridges and sandy slopes. Sandy soil.
			Steele shale.	Ks		2500–3000	Dark-gray shale containing fossiliferous concretions, with thin beds of sandstone.	Broad valleys, mostly covered by Quaternary deposits. Clay soils.
		COLORADO GROUP	Niobrara limestone.	Kn		325–400	Impure chalky limestone and gray limy shale. Weathers yellow.	Yellow bluffs and valleys mostly covered by Quaternary deposits. Rich soil.
			Benton shale. (Mowry shale member.)	Kb (Kmr)		700–1000 (100)	Gray shale containing dark concretions, with gray sandstone and concretions near the top. Hard gray shale, weathers light, with many fish scales. Dark-gray shale, thin sandstone, and bentonite.	Valleys and slopes, mostly covered by Quaternary deposits. Clay soil.
	L. CRET.		Cloverly formation.	Kc		70–100	Hard gray sandstone and purple to gray sandy clay.	Ridges and rocky slopes. Thin sandy soil.
CRET. OR JUR.			Morrison formation. UNCONFORMITY	Km		150–200	Massive green shale with thin limestones and sandstones.	Slopes mostly covered by talus. Clay soil.
TRIASSIC OR PERMIAN ?			Chugwater formation.	Ꞧc		1100	Red sandy shale, fine-grained massive sandstone, mostly red, and heavy beds of gypsum near base.	Ridges, buttes, and slopes. Red sandy soil, mostly barren.
CARBONIFEROUS	PENNSYLVANIAN		Forelle limestone.	Cf		0–20	Gray limestone, locally gypsiferous.	Rocky slopes. Thin, limy clay soil.
			Satanka shale. UNCONFORMITY	Cs		0–230	Red sandy shale with local gypsum deposits.	Valley with red sandy soil.
			Casper formation.	Cc		800–1000	Gray to red sandstone, gray to purple limestone, and red shale. Mostly red sandstone to south and west; limestone to north and east.	Mountain slopes and rocky ledges. Soil mostly thin and sandy.
PRE-CAMBRIAN			Granite, gneiss, and schist.				Mainly Sherman granite, with subordinate gneiss, schists, and acidic and basic intrusive rocks.	Rugged mountains with numerous rock exposures.

GENERALIZED SECTION FOR THE SHERMAN QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.

System.	Series.		Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
TERTIARY	MIOCENE		Arikaree formation. UNCONFORMITY	Ta		200–250	Sand, gravel, and bowlder beds, with local limestone lens.	Wide, nearly smooth plains. Good soil and pasture land.
	OLIGOCENE	WHITE RIV.	Brule clay.	Tb		250	Massive pinkish sandy clay, with gravelly streaks.	Badlands. Poor soil.
			Chadron sandstone. UNCONFORMITY	Tc		20–100	Massive brown sandstone, merging into sand and gravel.	Rocky ledges and plateaus. Sandy soil.
CRETACEOUS	UPPER CRETACEOUS		Fox Hills sandstone.	Kfh		700+	Gray sandstone and sandy shale.	Ridges and sandy slopes. Sandy soil.
		MONTANA GROUP	Pierre shale.	Kp		5000	Dark-gray shale containing fossiliferous concretions, with thin beds of sandstone.	Valleys and slopes, mostly covered by Quaternary and Tertiary deposits. Clay soil.
		COLORADO GROUP	Niobrara limestone.	Kn		325–400	Impure chalky limestone and gray limy shale. Weathers yellow. Massive gray limestone at base.	Yellow bluffs and valleys, mostly covered by Quaternary deposits. Rich soil.
			Benton shale. (Mowry shale member; not shown on map.)	Kb		700–1000	Gray shale containing dark concretions, with gray sandstone and concretions near the top. Hard gray shale, weathers light, with many fish scales. Dark-gray shale and thin sandstones.	Valleys and slopes, mostly covered by Quaternary deposits. Clay soil.
	L. CRET.		Cloverly formation.	Kc		70–100	Hard gray sandstone and purple to gray sandy clay.	Ridges and rocky slopes. Thin sandy soil.
CRET. OR JUR.			Morrison formation.	Km		150–200	Massive pale-green to maroon shale with thin limestones and sandstones.	Slopes mostly covered by talus. Clay soil.
JURASSIC			Sundance formation. UNCONFORMITY	Js		30–60	Buff slabby sandstone and sandy gray shale.	Slopes mostly covered by talus. Sandy soil.
TRIASSIC OR PERMIAN ?			Chugwater formation. UNCONFORMITY	Ꞧc		800–1000	Red sandy shale, fine-grained massive sandstone, mostly red, and thin limestones and deposits of gypsum near the base.	Ridges, buttes, and slopes. Red sandy soil, mostly barren.
CARBONIFEROUS	PENNSYLVANIAN MISS. ?		Casper formation.	Cc		800–1000	Gray to red sandstone, gray to purple limestone, and red shale. Gray to reddish-brown sandstone and conglomerate at the base.	Mountain slopes and rocky ledges. Soil mostly thin and sandy.
PRE-CAMBRIAN			Granite, gneiss, and schist.				Mainly Sherman granite, with subordinate gneiss, schists, and acidic and basic intrusive rocks.	Rugged mountains with numerous rock exposures.

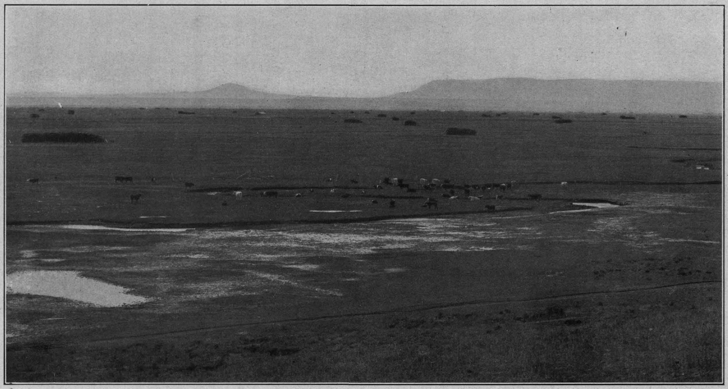


FIGURE 4.—LARAMIE PLAINS, LOOKING SOUTHWEST FROM RIDGE 2 MILES NORTH OF MANDEL, WYO.
Little Laramie River in foreground. Sheep Mountain to left of center.

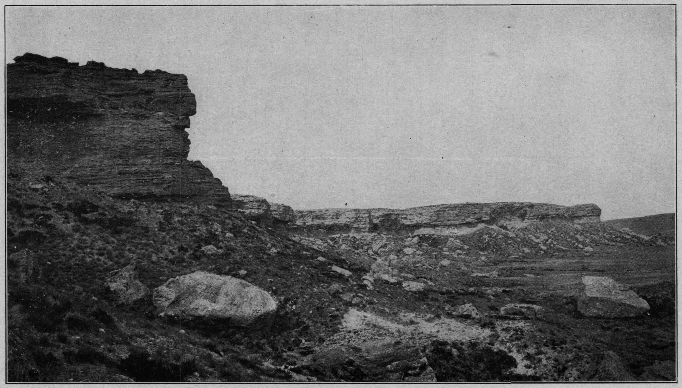


FIGURE 5.—CONGLOMERATE OF THE ARIKAREE FORMATION LYING ON BRULE CLAY.
Near Horse Creek, in T. 17 N., R. 70 W. Looking south.

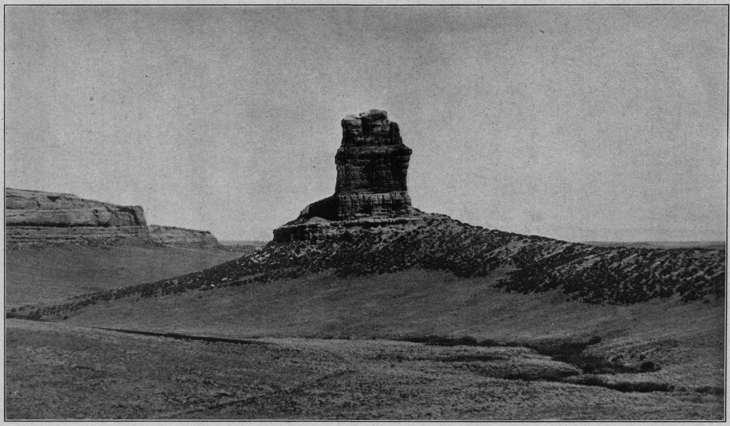


FIGURE 6.—STEAMBOAT ROCK, COMPOSED OF MASSIVE SANDSTONE IN THE CHUGWATER FORMATION.
Twenty-six miles southwest of Laramie, Wyo. Looking north.

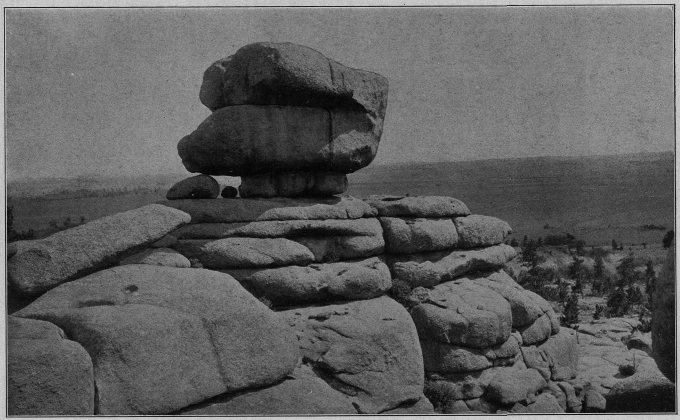


FIGURE 7.—SHERMAN GRANITE ON SUMMIT OF LARAMIE MOUNTAINS, WEST OF SHERMAN, WYO.
Showing horizontal sheeting and rounded forms resulting from weathering. Wide rolling plain of the mountain plateau in the background. Looking north.

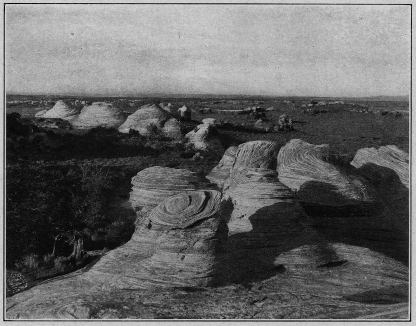


FIGURE 9.—CROSS-BEDDED SANDSTONE IN THE CASPER FORMATION, SAND CREEK, WYO.

FIGURE 10.—CHIMNEY ROCKS ON SOUTH BANK OF HORSE CREEK, EAST OF DAVIS RANCH, COMPOSED OF FOX HILLS SANDSTONE.

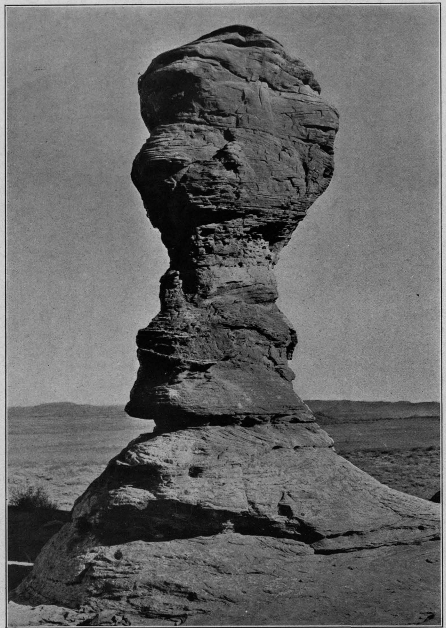


FIGURE 8.—MONUMENT OF CROSS-BEDDED RED SANDSTONE OF THE CASPER FORMATION AT RED BUTTE, WYO.
The monument is about 20 feet high.

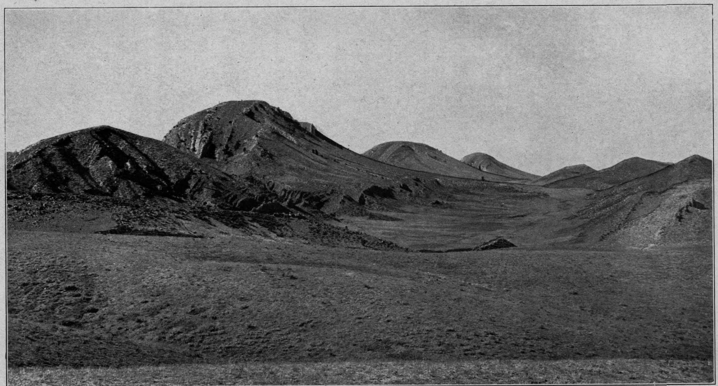


FIGURE 11.—LIMESTONE FRONT RIDGE ON EAST SIDE OF LARAMIE MOUNTAINS, WEST OF HORSE CREEK STATION, WYO.
Looking north. High ridges, Casper formation; Red Valley and low ridge of Cloverly sandstone to right.

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52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
70	Washington	D. C.-Va.-Md.	50
71	Spanish Peaks	Colorado	25
72	Charleston	West Virginia	25
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74	Coalgate	Indian Territory	25
75	Maynardville	Tennessee	25
76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
83	New York City	New York-New Jersey	50
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109	Cottonwood Falls	Kansas	25
110	Latrobe	Pennsylvania	25
111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
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128	Aladdin	Wyo.-S. Dak.-Mont.	25
129	Clifton	Arizona	25
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132	Muscogee	Indian Territory	25
133	Ebensburg	Pennsylvania	25
134	Beaver	Pennsylvania	25
135	Nepesta	Colorado	25
136	St. Marys	Maryland-Virginia	25
137	Dover	Del.-Md.-N. J.	25
138	Redding	California	25
139	Snoqualmie	Washington	25
140	Milwaukee Special	Wisconsin	25
141	Bald Mountain-Dayton	Wyoming	25
142	Cloud Peak-Fort McKinney	Wyoming	25
143	Nantahala	North Carolina-Tennessee	25
144	Amity	Pennsylvania	25
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152	Patuxent	Md.-D. C.	25
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155	Ann Arbor	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	25
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158	Rockland	Maine	25
159	Independence	Kansas	25
160	Accident-Grantsville	Md.-Pa.-W. Va.	25
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‡ These folios are out of stock.

§ These folios are also published in octavo form.

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