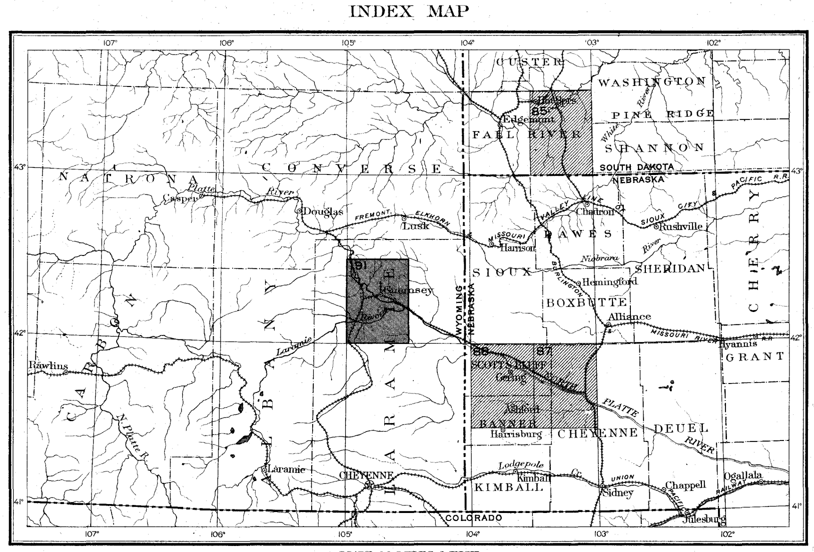
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

HARTVILLE FOLIO

WYOMING

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE HARTVILLE FOLIO — AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

LIBRARY EDITION

HARTVILLE FOLIO
NO. 91

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS S. J. KUBEL, CHIEF ENGRAVER
1903

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

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 which are most important 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

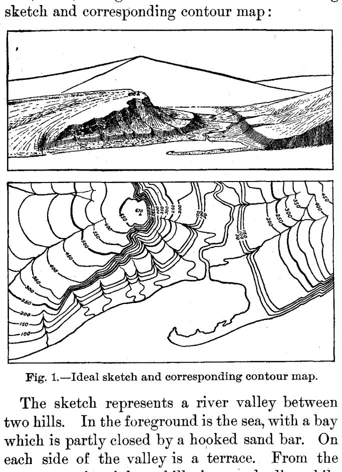


Fig. 1.—Ideal sketch and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the slope at the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while 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 sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours — say every fifth one — are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise 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.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Water courses are indicated by blue lines. If the streams flow the year round the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this case it is "1 mile to an inch." 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 of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.— The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on a scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. 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 the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be discovered by observing their relative positions. This relationship holds except in regions of intense disturbance; sometimes in such regions the disturbance of the beds has been so great that their position is reversed, and it is often difficult to determine the relative ages of the beds from their positions; then *fossils*, or the remains of plants and animals, are guides to show which of two or more formations is the oldest.

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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.

When two formations are remote one from the 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 found in the rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors.
	Neocene {Pliocene, Miocene}	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias {Jurassic, Triassic}	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	Ꞓ	Pinks.
	Algonkian	A	Orange-browns.
	Archean	Æ	Any colors.

a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern and its letter-symbol on the map 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 given formation, its name should be sought in the legend and its color and pattern noted, when 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface.

In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same name 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 the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

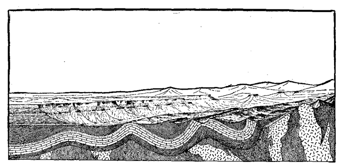


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

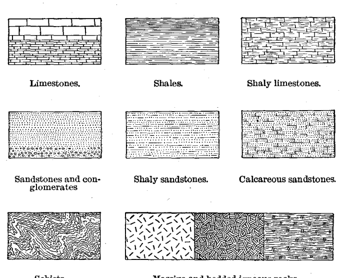


Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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 that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which 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 slipped past one another. Such breaks are termed *faults*.

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. 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 well-founded inference.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has swelled upward from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

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

The horizonal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their 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 plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond 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 which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE HARTVILLE QUADRANGLE.

By W. S. Tangier Smith.

GEOGRAPHY.

GENERAL RELATIONS.

Area and position.—The Hartville quadrangle extends in latitude from 42° to 42° 30′, and in longitude from 104° 30′ to 105°. Its length is 34.5 miles (55.5 kilometers) and its average width 25.6 miles (41.2 kilometers), giving an area of 884.85 square miles (2291.7 square kilometers). It includes a little more than one-eighth of Laramie County, Wyo., lying near the center of the northern half of that county. It is situated near the western margin of the Great Plains, along the eastern flank of the Rocky Mountains. West of the quadrangle, at a distance of about 20 miles, is the eastern base of the Laramie Mountains, of which uplift the mountainous northern portion of the quadrangle may be considered a part.

TOPOGRAPHY.

Relief.—The range of altitude within the quadrangle is moderate. The greatest difference in elevation amounts to only 1525 feet, and the extremes are about 22 miles apart. The lowest point is at the eastern margin, in the valley of North Platte River, northeast of Fort Laramie, where the altitude is 4225 feet above sea level; the highest point is at the northern margin, a little more than 5 miles northeast of 4 J Ranch, where an altitude of 5750 feet is reached. The highest portions are toward the northern and southern margins, and from these regions there is a general slope toward North Platte River. The maximum difference in elevation for any one part of the quadrangle is in Haystack Range, on the east side of Whalen Canyon, where the rise from the stream bed to the summit of the range, in a distance of one mile, is nearly 1000 feet.

One of the most marked topographic features of the quadrangle is the cliff whose southern end forms the western wall of Whalen Canyon, and which, beginning at a point about 2 miles east of Guernsey, runs in a north-northeasterly direction to a point beyond the northern limit of the quadrangle. The height of the cliff ranges within the quadrangle from about 100 feet at its southern end to more than 500 feet at the northern border of the map. While presenting a general uniformity of direction, the line of the cliff is sinuous, being more or less modified by erosion, which has notched the scarp with small valleys. The top of the cliff, throughout the greater part of its length, is capped with a resistant quartzite; but south of Sunrise this quartzite cap has been removed to a greater or less extent, and at a number of points the underlying rocks have been so eroded as to form passes in the hills, through several of which roads have been made.

A little more than a third of the northern half of the quadrangle is occupied by an upland whose southern portion resembles a shallow amphitheater, opening to the southwest, while the northern and northeastern portions have the character of a dissected plateau. The upland (which will be referred to as the Carboniferous upland) is bounded on the east by the cliff just described. On the south it is bounded, roughly, by North Platte River. On the west it terminates in the ridge lying east of Cassa and running in a north-northeasterly direction. The highest part of the rim is on the northeast. This area is much dissected, and among the resulting forms are many scattered knobs, of no great altitude. Some of the numerous valleys are quite open, especially in the northern part, while in the southern part they are mainly sharp, V-shaped canyons. The North Platte has cut deep gorges through both the eastern and the western rim of the upland just described, near the southern ends. Southeast of Cassa the gorge presents very abrupt cliffs, having a maximum height of about 600 feet.

Just east of Whalen Canyon and its northward prolongation is a broken ridge, or series of ridges, which forms the most rugged part of the quadrangle and one of its highest regions. Some parts of this ridge, in the granites and schists, are so rough that they can be traversed only on foot. The ridge varies greatly in altitude, and at a number of places has been cut across by erosion, forming passes. It is connected with the cliff already described, at two points, one a rather elevated saddle west of Waterhole Ranch, the other a comparatively low pass at the north end of Whalen Canyon. South of this pass the ridge is known as Haystack Range. At several points in the southern half of this range the summits are flat topped, being capped with nearly horizontal beds of quartzite and limestone.

Between the Carboniferous upland and the eastern border of the quadrangle there are, in addition to the ridges just described, a number of elevations of moderate height, formed by outcrops of hard rocks, the lower and more level portions of the area consisting of rather soft and easily eroded rocks. A glance at the geologic map will show the location of these hills. Casebier Hill is an exception, being formed of the softer deposits and protected from erosion by a capping of gravel.

In the northwest corner of the quadrangle, north of Cassa and west of the upland already described, there is a plateau-like region having a general slope to the southwest and surmounted by several flat-topped buttes of moderate size. This plateau is formed of hard sandstone, through which the streams have cut steep-walled valleys several hundred feet in depth, generally reaching the softer beds below.

The portions of the quadrangle not already described have a more or less uniform topography, the forms being cut in rather soft though coherent deposits. The predominant features are broad, nearly level stretches, surmounted here and there by higher mesas, the whole much dissected by streams, which give rise to more or less open, flat-bottomed valleys bordered by cliffs of varying height and irregular contour.

Drainage.—The two main drainage lines of the quadrangle are North Platte River and its tributary, Laramie River, which rise far to the southwest in the mountains of northern Colorado. Both streams are meandering throughout their course in this quadrangle. In its lower stretches, southeast of Guernsey, the North Platte occupies a flat-bottomed valley having an average width of about a mile, and bordered by slopes or cliffs which vary in height from about 50 to 250 feet, and which are particularly abrupt on the south. Northwest of Guernsey the river is confined, for a considerable part of its course, within walls of hard rock; but at a few points where it has had opportunity to cut laterally (as near Wendover, and also near Cassa), flat-floored, open valleys have been formed.

Laramie River and its tributaries, Chugwater Creek and North Laramie River, throughout their length within the quadrangle, flow through comparatively broad and open valleys. As is the case with the North Platte in its lower stretches, these valleys are bordered by slopes of varying height and abruptness.

Many of the streams of the quadrangle flow intermittently for the whole or a part of their course, their beds generally being dry except for a short time after a rain. All the streams which head within the quadrangle, including many which occupy the deeper and more important minor canyons, are of this intermittent character, at least for a part of their course.

Over most of the Carboniferous upland the drainage, following the slopes, tends toward a central axis, the streams, with a few exceptions, flowing from all sides into the North Platte by way of Broom Creek.

The nearly flat floor of Whalen Canyon is trenched by smaller valleys (chiefly in its lower portion), and the main stream occupies one of these trenches, well over on the canyon's eastern side.

In some of the more nearly level portions of the quadrangle the small amount of drainage water tends to collect in small lakes or ponds, some of which are ephemeral. Such lakes are found particularly in the region about Wheatland, in the southwestern part of the quadrangle.

CLIMATE.

The intermittent character of many of the streams is due to the dryness of the climate. The summers are comparatively short and hot, while the winters are long and severe. The rainfall is small, and during the summer months is generally confined to sudden showers, which, though the precipitation may be considerable, are of so short duration, and the run-off is so rapid, that there is small chance for saturation, even near the surface, and the ground is soon as dry as before. It is not uncommon for a summer rainfall to be wholly evaporated before reaching the ground. During the winter months the surface of the ground is so cold and the air is so dry and sharp that, although a considerable amount of snow may fall, it is, in some cases, evaporated without apparently moistening the dust.

VEGETATION.

Most of the region south of North Platte River is treeless, the vegetation consisting of a sparse growth of grasses, cactus, and other low-growing plants. The same is true of the more nearly level stretches north of the North Platte, east of the Carboniferous upland. The slopes of the canyons, especially those of the more important stream courses, are dotted with scattered pines (*Pinus ponderosa*). On the rugged hills east of Whalen Canyon there is a rather open growth of pines. The upland in the northern part of the quadrangle, and also the hills north and northeast of Cassa, support a scattered growth of pines, and some of the canyon slopes are well wooded. Cottonwood trees are common along some of the stream courses, also box elders, and there are occasional willows.

CULTURE.

As is generally the case, culture is determined in the main by geologic and climatic conditions. For the most part the country is too rugged or barren to be favorable for any industry but grazing. Not only is the soil thin, but water is scarce, except along the larger stream courses, so that settlements are not numerous. The scattered farms are mainly along the river courses, in the more open parts of the valleys. The southwest corner of the quadrangle, however, is a marked exception; there the level uplands around Wheatland are extensively cultivated, and settlements have been made at a number of places, the town of Wheatland being the center of the agricultural community. Fort Laramie, in the eastern part of the quadrangle, is a small settlement, the remains of a former military and trading post. The town of Guernsey, in the center of the quadrangle, has sprung up in the wake of the Burlington and Missouri River Railroad, while the settlements at Hartville and Sunrise, a few miles to the north, are due to the development of the iron mines of the region.

The roads are rather numerous, and in general are fairly good, considering the character of the country. They follow, for the most part, natural rather than artificial lines, except in the level region around Wheatland, where many of them run along the section lines, a tendency which is increasing with the settlement of the region.

As a result of the scanty rainfall and the thin soils, irrigation is usually necessary for the raising of crops; but owing to the elevation of the more nearly level parts of the quadrangle above the perennially flowing streams, irrigation is confined, in general, to the valleys bordering these streams. Even there, on account of the meandering of the streams, which causes them to swing, now on one side, now on the other, against the abrupt cliffs bordering the valleys, it is impracticable in some places to run a canal for any great distance.

The perennial streams of the quadrangle are North Platte and Laramie rivers and Chugwater, Horseshoe, and Cottonwood creeks. Of these, all except Cottonwood Creek are, or could be, utilized directly for purposes of irrigation. The water supply of the Laramie and the North Platte is so large that those streams would be little affected by the demands made upon them for irrigation within this quadrangle. The supply of water in Cottonwood Creek is not sufficient for irrigating the agricultural lands along its course within the quadrangle, but could be made so by the construction of storage reservoirs higher up the creek. At favorable points on some of the intermittent streams, also, small storage reservoirs might be constructed, which would furnish water for irrigating limited areas. In fact, a number of reservoir claims have already been taken up.

A considerable area along the lower stretches of Horseshoe Creek within this quadrangle is irrigated by canals and ditches. Canals have been built, also, in the valley of the North Platte, near Fort Laramie. The level uplands around Wheatland are irrigated by canals and ditches which bring water from Laramie River, about 27 miles southwest of Wheatland. About 8 miles northwest of Guernsey, and south of North Platte River, 100 acres have been successfully irrigated by water drawn from the river by two centrifugal pumps. The products of these irrigated areas are alfalfa, wheat, oats, corn, potatoes, and other vegetables.

So far as known, there are no deep wells in this quadrangle. While some of the conditions are favorable to artesian wells of moderate depth in the Arikaree formation, the absence of an impervious covering to confine the water makes their occurrence improbable; and the likelihood of obtaining artesian water from the rocks beneath the Arikaree is not much greater.

GENERAL GEOLOGY.

The formations of the Hartville quadrangle comprise metamorphic, deep-seated (plutonic) igneous, and sedimentary rocks. They are representatives of the Algonkian, Carboniferous, Jurassic, Cretaceous, Neocene, and Pleistocene systems.

METAMORPHIC ROCKS.

ALGONKIAN PERIOD.

Whalen group.—The metamorphic and associated granitic rocks underlie the sedimentary rocks of the quadrangle, and their outcrops constitute but a small part of its area. The metamorphic rocks (to which the name Whalen group has been given, from their typical occurrence along the walls of Whalen Canyon) consist of a series of gneisses, schists, quartzites, and limestones, all having their planes of schistosity vertical or dipping at a high angle.

The rocks of the Whalen group as a whole are found in the northeastern part of the quadrangle, where they form the lower portion of the cliff that borders the Carboniferous upland on the east, extending almost to its southern limit, west of Whalen Canyon. They also form the lower part of the cliffs at the east side of Hartville Canyon, and occasional outcrops are found on the west side of the same canyon. They form a considerable portion of Haystack Range and its northward extension, as well as the lower prominences to the south of the road south of Haystack Range, and part of the low hills south of Waterhole

Ranch. Their strike and dip vary considerably; some of the general directions of strike in Haystack Range are indicated by the directions of the granite and pegmatite dikes intruded in the schists. In addition to these occurrences there are several small areas of schist a little south of Laramie River, about the middle of the quadrangle.

The northernmost occurrence of the limestones of the Whalen group is a little more than a mile from the northern edge of the quadrangle, in the lower part of the cliff forming the eastern border of the Carboniferous upland. Thence they follow the cliff to the northern limit of the granites, northwest of Waterhole Ranch, and south of this they not only form a part of the cliff, but occupy a large portion of the valleys between the cliff and the granites. They are generally dark gray, fine grained and rather thin bedded, dipping at a very high angle and having a general strike in the direction of the valleys. They are always siliceous, containing many threads, veins, or thin sheets of silica, which run mainly in the direction of the bedding planes. In places they contain rather thin interbedded layers of yellowish quartzite, and are associated with a greater or less amount of schistose quartzite, containing occasional thin interstratified lenses of limestone. The limestones, which run in a west-southwesterly direction, cross the low divide at the head of Whalen Canyon and for the most part follow the western side of that canyon to a point about 2 miles south of Frederick, where they disappear. The limestones on the eastern border of the strip described are usually resistant to weathering, and form a series of low hills or ridges within the valley which they follow.

Another occurrence of the limestones begins just west and south of Sunrise, and follows the canyon from Sunrise to Hartville, then the eastern side of Hartville Canyon for about a mile to the southeast, where it turns to the east and follows the ridge a little more than a mile south of Sunrise, till it reaches Whalen Canyon, where it ends. The limestone forms here a rather broad strip, covering the whole of this ridge and extending a short distance north of it. Along this ridge the strike of the rocks is east and west, with a very high dip to the north. The limestones of this area are much like those of the area to the north. They are always more or less siliceous, and everywhere contain numerous narrow quartz seams. The color is gray or pink, the pink rocks being somewhat translucent in thin fragments. The limestones are associated with a minor proportion of a more or less calcareous quartzite. At two points there were seen beds of pink, schistose, siliceous limestone, about 50 feet thick, the schistose surfaces silvery with minute flakes of light-colored mica. This limestone contains a considerable percentage of magnesium, together with more or less iron in the form of ferrous carbonate.

Another area of gray and pink siliceous limestone beds, having a general strike a little south of east, occurs along the edge of the hills north of Guernsey, outcropping at intervals from the west bank of North Platte River just south of Fairbank, on the west, to Whalen Canyon on the east. These limestones are associated mainly with amphibole-schists.

Quartzites and micaceous schists form the greater part of the exposed rocks of the Whalen group, and in places they grade into each other so that no definite separation can be made. The quartzites are generally rather dark-gray, fine-grained rocks, with a more or less pronounced schistose character. As already mentioned under the limestones, some of these quartzites are more or less calcareous. Under the microscope they are seen to be composed largely of a mosaic of small quartz grains, of variable dimensions, with a more or less marked banded arrangement. In most of these rocks many of the quartz grains are elongated in the direction of the plane of schistosity. Associated with the quartz is a variable amount of muscovite and biotite, the latter usually predominating. In addition to this there is sometimes a minor proportion of feldspar. The micaceous schists range from a fine- and even-grained quartzitic rock to a moderately coarse-grained rock having abundant broad flakes of mica. Both muscovite and biotite are plentiful, the latter usually in excess. Small garnets are also found here and there. The schists are generally dark gray to nearly black. Since both the schists and the quartzites dip everywhere at a high angle, their weathered surfaces are often rendered extremely rough by projecting points and slabs of the rock. The finer-grained rocks frequently tend to break up, vertically, into splintery fragments from a fraction of an inch to 6 or 7 feet in length. In the schists and quartzites around Whalen Canyon white quartz veins are common, their width ranging from an inch or two up to about 2 feet. These rocks generally have a fairly constant dip for considerable distances, but at one or two points, in the neighborhood of the numerous pegmatite dikes southwest of Government Farm, they are much contorted.

Besides the mica-schists, the Whalen group contains schists of which amphibole is the predominant mineral. These amphibole-schists, so far as observed, are to be found mainly on the west side of Whalen Canyon. They are either fine grained, with a pronounced schistosity, or, more commonly, of microscopic grain and generally slaty character, cleaving into thin plates with rather smooth surfaces of separation. Under the microscope they are seen to be composed mainly of quartz and a light-green hornblende, with, in some cases, a few scattered flakes of biotite.

In addition to these massive, fine-grained amphibole-schists there are a few narrow dikes of coarser-grained, gneissic, amphibole rocks occurring with the schists on the east side of Whalen Canyon. They are composed largely of hornblende, with a minor proportion of feldspar (mainly orthoclase) and a still smaller amount of quartz, and, in addition, contain scattered grains of magnetite.

The gneisses associated with the schists and quartzites of the Whalen group are of rather limited occurrence, being found mainly in the isolated hills south of Waterhole Ranch, along the eastern slopes of the northern end of Haystack Range, and in the hills to the north, near the limit of the granite. They are generally medium to rather fine grained, and dark gray in color.

The Whalen group, being overlain by Carboniferous rocks, must belong to an earlier period. It is possible that the group was once covered by deposits older than the Carboniferous, but if so they must have been wholly removed before the Carboniferous sediments were laid down, since there are now no traces of intermediate deposits. The Whalen group is entirely different from any of the rocks younger than those of Algonkian age occurring along the eastern slope of the Rocky Mountains, and it closely resembles the Algonkian of the Black Hills core. In both districts the sedimentary rocks are penetrated by granitic intrusions and metamorphosed, and are separated from the overlying deposits by a great unconformity. The group is accordingly assigned to the Algonkian, on the basis of lithologic character and general relations.

IGNEOUS ROCKS.

ALGONKIAN PERIOD.

Granite.—The granitic rocks of the quadrangle are found over a comparatively limited area, penetrating the metamorphosed strata of the Whalen group. They include several varieties, though they are mainly confined to two—a moderately coarse-grained granite and a pegmatite. The former occurs both in masses of considerable size and in dike-like bodies which follow in a general way the bedding of the schists, and range in thickness from a fraction of an inch to several hundred feet. In some places the dikes are very numerous. Where the granite is massive the areas are usually elongated in a direction roughly parallel to the strike of the schists. The rock has a general grayish appearance at a distance, though in most cases it is seen, on a nearer view, to be characterized by a more or less pronounced reddish tinge. In some localities it presents a well-defined system of joints. The granite weathers in bold, rounded forms, giving rise to generally rugged topography.

Owing to differential weathering the surface of the rock is usually rough, and the prominence of the comparatively large feldspars gives it a generally porphyritic appearance. The essential constituents are feldspar, quartz, and biotite. The feldspars are mainly orthoclase and microcline, with a minor proportion of plagioclase (albite or oligoclase). The potash feldspars in the rock generally have a reddish tinge. The quartz occurs in scattered glassy patches, which under the microscope are seen to be aggregates of small quartz grains. Biotite is usually the only ferromagnesian mineral present, though here and there a small proportion of green hornblende is found. The granite gives some evidence of having been subjected to crushing since its intrusion.

The areas at the southern end of Haystack Range and just northeast of Frederick appear to be composed wholly (except for a few dikes of pegmatite and aplite) of the coarse-grained granite. A considerable part of the area west of Waterhole Ranch, including the occurrence at the head of Whalen Canyon, is also of this granite, as are, for the most part, the dikes already referred to.

In addition to the granite just described, there are several varieties of granitic rocks (exclusive of the pegmatite and aplite) which form a minor proportion of the ridge west and of the hills south of Waterhole Ranch. They occur massive in the former locality and in dikes in the latter. They range from a medium to a rather fine grain, and are in part hornblende-granites and in part biotite-granites. The amount of contained plagioclase is variable, and some of the rocks are to be classed with the monzonites rather than with the granites.

Cutting the areas of granite which have been described, or near their margins, are occasional dikes of a fine-grained, light-colored aplite, which in most cases is free from mica. Pegmatite, though occurring under somewhat similar conditions, is found mainly in two local groups of dikes cutting the rocks of the Whalen group. One of these groups is in the western end of the hills just south of Waterhole Ranch; the other is in the Haystack Range, southwest of Government Farm. The dikes range in width from 2 or 3 inches up to about 25 feet in the northern group, and to several hundred yards in the southern series. The majority of them have a generally parallel direction, with a tendency to follow the strike of the rocks into which they are intruded. In addition to these two groups there are a number of dikes of coarse pegmatite cutting the granites and schists in the hills just southeast of Government Farm. They vary in width from a fraction of a foot up to about 4 feet, and either follow the strike of the rocks or cut across it at a small angle. As a rule the pegmatite is coarse grained, though it varies considerably. The larger dikes are not always the coarser grained, the opposite being sometimes the case. A number of dikes which are coarse grained in the center have narrow, fine-grained margins. The pegmatite is generally white, or nearly so, but two dikes were seen in which the rock was of a pale-reddish shade. Much of the pegmatite consists of quartz and orthoclase, the individual crystals having a maximum diameter of several feet. A number of the dikes contain thin plates of muscovite, many of them small, but some of considerable size, up to nearly a foot in width. In the southern group of dikes black tourmaline crystals are common, either near the margins of the dike or scattered through it. They vary considerably in size, occurring as small needles in some dikes, even the coarser grained, while in several instances they are unusually large, reaching a maximum length of about 3 feet.

SEDIMENTARY ROCKS.

CARBONIFEROUS PERIOD.

Guernsey formation.—The Guernsey formation consists of limestone with some sandstone and quartzite members, resting unconformably upon the planed-off surface of the Whalen group and the intruded granites. This surface, wherever seen in section, appears to be almost perfectly even. On the face of the cliff bordering the Carboniferous upland on the east the contact between the two formations is seen as an almost straight line which can be followed nearly the entire length of the cliff, a distance of between 15 and 20 miles. The rocks of the formation outcrop along the line of this cliff from the northern edge of the quadrangle to a point east of Hartville. South of this point they occur as isolated areas capping the summits of the hills east of Hartville Canyon, and also as a rather narrow strip along the western side of the canyon. This strip connects with the strip just described as bordering the cliff of the Carboniferous upland. In addition to these occurrences there are exposures of the formation in the hills both north and south of Waterhole Ranch. Small areas also occur capping a number of the granitic summits in the southern part of Haystack Range and a hill of Algonkian schists just south of that range.

The formation ranges in thickness from about 75 feet to about 200 feet, the variation being due to the irregularities of its upper surface produced by erosion prior to the deposition of the sediments of the overlying Hartville formation.

The following section from near Fairbank will show the general character of the beds composing the formation:

Geologic section of Guernsey formation.

	Feet.
Red quartzite of the Hartville formation	..
Unconformity	..
Dark-gray, fine-grained limestone, about	30
Light-gray, fine-grained limestone, about	40
Fine-grained gray limestone with purplish tinge, about	30
Yellow, fine-grained, massive limestone.	18
Red fossiliferous sandstone	6
Fine-grained gray limestone	5
Moderately coarse-grained calcareous sandstones, dull reddish or yellowish in color	4
Nearly white conglomeratic quartzite, at the base	10
Unconformity.	

The lowest member of the formation is a quartzite, usually light colored or nearly white, though frequently with reddish streaks or with a generally reddish tinge. Where weathered it is commonly brownish or yellowish. It is in part fine grained, and in part conglomeratic, especially near its base. The original sandstone or conglomerate of which it is composed has been cemented by silica into a hard quartzite. The conglomerate ranges from fine grained to rather coarse grained, all the pebbles, in general, being composed of quartz, although at a few places pebbles of schist occur associated with those of quartz.

The quartzite, though thin (varying in thickness from about 3 to about 20 feet), is persistent over the area of the Guernsey formation exposed in the quadrangle, and is important topographically, since, owing to its resistant character, erosion has left it at a number of points capping cliffs and forming flat-topped hills where the overlying red quartzite of the Hartville formation has been removed.

The beds overlying the conglomeratic quartzite include both sandstone and limestone, and are somewhat variable in continuity and in thickness. Of these beds, the gray fossiliferous limestones near the top of the formation are the most important and the most persistent. In physical character these limestones much resemble the Pahasapa limestone of the Black Hills, of which they may be representatives for this region.

Hartville formation.—On the uneven surface produced by erosion of the upper beds of the Guernsey formation the sediments of the Hartville formation were laid down. The outcrops of the rocks of this formation cover a considerable part of the northern half of the quadrangle. The largest area is in the Carboniferous upland northwest of Guernsey, where, with few exceptions, they form the surface rocks.

The Carboniferous rocks in this whole region have been unequally eroded, so that they are much thinner on the east than on the west; nevertheless, the boundaries of what has been called the Carboniferous upland conform very closely to those of this area of these rocks, and its general form is an index of the underlying structure of the formation, to which it is largely due. This structure consists of several simple folds, whose axes pitch, on the whole, gently to the southwest. They rise toward the north, and to the south pitch under the Tertiary deposits. The central part of the Carboniferous upland is a very open synclinal trough. The western rim is formed by an anticline having a comparatively steep dip to the west and a gentle dip toward the east; the eastern rim is part of an anticline having a gentle slope to the west and a steeper slope to the east. The summit of this eastern anticline has been cut into and largely removed by erosion. Its former position is marked in part by the southern and more open portion of Whalen Canyon, and by the northern end of Haystack Range. These characters are brought out on the Structure Section sheet. Looked at more broadly, the region just described is seen to be the southern portion of a more extensive dome-shaped uplift, somewhat modified by minor folds.

There are, in addition to this large area of the Hartville formation, the smaller areas already mentioned as occurring toward the eastern margin of the quadrangle, a small area just south of Bear Creek near the western margin of the quadrangle, and a number of small patches in the region around Guernsey.

The Hartville formation has a thickness of about 700 feet, and consists mainly of limestone, with a minor proportion of sandstone and a still smaller amount of shale, these rocks occurring in beds which vary in thickness from somewhat less than a foot to more than 50 feet. The thickness of the individual beds also varies somewhat from point to point, and in some cases they wedge out and disappear.

The limestones are fine grained and compact, generally light to dark gray, though frequently with a reddish or purplish tinge, and occasionally of a pale yellowish shade. Many of the beds are more or less siliceous, and a number of them contain impure chalcedony (chert) in scattered nodules or strings of nodules, or in thin sheets. The sandstones are medium grained, and for the most part occur in thin beds intercalated with the limestones. They range in thickness from 6 inches to about 50 feet, the majority of the beds being from 2 to 5 feet thick. Several exhibit cross bedding. The rocks are generally gray or pale buff to nearly white, though a few of the beds are red. Most of the sandstones are more or less calcareous, especially the gray beds.

At the base of the formation is a medium-grained sandstone, nearly everywhere cemented by silica into a hard quartzite. It has an average thickness of about 50 feet, and is generally characterized by a deep brownish-red color, usually with streaks or patches of white. In places it is entirely white, or shows only a tinge of red. Owing to the erosion of the surface on which these rocks were laid down, the line of contact is very uneven, and occasional tongues of the red quartzite project downward into the rocks beneath, some of them 100 feet or more below the general level of the bottom of the quartzite. These projecting tongues of quartzite form marked features on the face of the cliffs about a mile east of Guernsey and on both sides of North Platte River at Fairbank (see figs. 3 and 4, on the Illustration sheet). The bottom bed, like the basal quartzite of the Guernsey formation, is resistant to weathering, and as a consequence we find either the lower quartzite alone, or both beds, with the intervening sandstones and limestones, not only capping the greater part of the cliff which borders the Carboniferous upland on the east, but also forming the Carboniferous outliers in the hills on the east side of Whalen Canyon, and capping wholly or in part the hills north and south of Waterhole Ranch.

In addition to the sandstones and limestones, there are several beds of shale or clay in the lower portion of the Hartville formation. They are for the most part of a deep-reddish color, though partly grayish green, or red flecked with green. They tend, in part at least, to separate into thin, papery fragments.

The rocks of the Hartville formation are in general resistant to weathering, and where they have been exposed by the removal of the overlying rocks, or have been cut into by streams, the massive limestones of which the formation is largely composed tend to form abrupt cliffs. Where erosion is rapid the canyons formed are narrow and steep walled. This is especially noticeable in the gorges cut by the North Platte, where the cliffs have a maximum height of about 600 feet (see fig. 5, Illustration sheet).

The determination of the Hartville and Guernsey formations as of Carboniferous age is based on numerous fossils which were found in several of the beds near the middle and toward the base, and which were identified by Dr. G. H. Girty, of the United States Geological Survey. The following species, which were found between 300 and 500 feet above the base and entirely within the Hartville, have been referred to the Upper Carboniferous (Missourian division):

Ambocœlia ? sp.	Orthothetes (or Derbya).
Archæocidaris spines.	Productus æquicostatus.
Aviculopecten occidentalis.	Productus cf. inflatus.
Derbya crassa.	Productus prattenianus.
Euomphalus sp.	Productus punctatus.
Fusulina cylindrica.	Productus semireticulatus.
Marginifera splendens ?.	Seminula subtilita.
Spirifer rockymontanus.	

Those obtained from the lower 200 feet, including the lower part of the Hartville, and referred to the Lower Carboniferous (Mississippian), are as follows:

Eumetria verneuiliana ?.	Pugnax sp.
Fish tooth.	Seminula subquadrata.
Productus gallatinensis.	Spirifier cf. Keokuk.
Productus lævicosta.	Spirifier striatus var. madisonensis.
Productus semireticulatus ?.	
Zaphrentis sp.	

Opeche formation (*Permian* ?).—The only occurrence of the Opeche formation within the quadrangle is a very narrow strip in the northwest corner, beginning about a mile and a half southeast of Cassa and running in a general northeasterly direction for about 5½ miles along the base of the hills which mark the western limit of the Hartville formation in this region. These rocks have a thickness of about 60 feet, and consist of bright-red sandstone, thin bedded, fine grained, and of only moderate hardness, with a minor proportion of red, flaky shale. They lie next above the Hartville formation, resting conformably upon a massive white sandstone at the top of the latter. The beds dip at a considerable angle, in a northwesterly direction. The determination of the age of the formation is based on stratigraphic evidence and on the physical characters of the rocks, as they conform, both in position and in general character, to the Opeche formation in the Black Hills, which is probably of Permian age.

Minnekahta limestone (*Permian* ?).—This formation occurs next above the Opeche, and rests conformably upon it. It consists of about 20 feet of limestone, appearing at the western base of the hills east and northeast of Cassa and running in a northeasterly direction. The limestone is pale gray in color, usually with a purplish tinge, and is generally fine grained and compact. It occurs in thin layers or sheets, which on weathering break up into plates or slabs ranging in thickness from about one-thirty-second of an inch to about 4 inches. The formation has a pronounced northwesterly dip, varying somewhat from point to point. Being rather resistant, and occurring between the soft Opeche formation below and the soft sandstones of the Spearfish formation above, the limestones have given rise, through erosion, to a series of low "hogback" hills or short ridges—a topographic form which is generally characteristic of an outcropping bed of hard rock between softer beds, all dipping at a considerable angle in one direction. This line of "hogbacks" runs in a northeasterly direction, following the outcrops of the formation. The limestone forms the summits and western slopes of the hills, the eastern slopes being developed largely on the softer Opeche rocks.

The rocks of this formation correspond in stratigraphic position and general physical characters to the Minnekahta or "Purple" limestone of the Black Hills, which has been determined as probably of Permian age.

JURATRIAS PERIOD.

Spearfish sandstone (*Triassic* ?).[1]—West of the Minnekahta limestone, and resting conformably upon it, is a narrow strip of the red Spearfish sandstone, more familiarly known as the "Red Beds." This area, as in the case of the Minnekahta and Opeche formations just to the east, is limited on both the north and the south, being covered with Tertiary deposits. In addition to this strip there is a small occurrence of the Spearfish formation about 2 miles east of the northwest corner of the quadrangle, where the overlying Tertiary rocks have been removed through erosion. This small mass is part of a larger area extending northward beyond the limit of the quadrangle. The formation has a thickness of about 450 feet, and consists of dark reddish-brown, rather soft sandstones, of medium and nearly uniform grain, with a very small proportion of light-colored sandstones in its lower half. The rocks are thin bedded, and here and there the surfaces of the beds are distinctly ripple-marked. In the occurrence northeast of Cassa the beds have a general northwesterly dip, the angle being very variable, ranging from about 12° to about 45°, and being higher on the east than on the west. In the lower third of the formation, there are long, thin lenses or sheets of white limestone, ranging in thickness from a few inches to several feet. Near the southern end of the area northeast of Cassa, and in the lower half of the formation, thin sheets of white, granular gypsum are common, lying one above another in groups, and separated by thin beds of the red sandstone.

The Spearfish sandstone, being soft, is worn down more easily than the rocks immediately above and below it, which accounts in part for the valley occupied by this formation northeast of Cassa. Further, not far above these rocks are the hard sandstones and quartzites of the Dakota formation, which characteristically form cliffs and mesas, and only a little below are the resistant limestones and sandstones of the Hartville formation, both serving to emphasize the contrast of the forms developed in the soft rocks.

No fossils were found in this formation. In stratigraphic position and general physical characters (including the presence of beds of gypsum) it corresponds to the Spearfish formation of the Black Hills.

Sundance formation (*Jurassic*).—Lying directly over the Spearfish are the sandstones of the Sundance formation. The outcrops of these rocks occur just west of the Red Beds, and also along the lower parts of the cliffs bordering the flat-topped hills in the northwest corner of the quadrangle. Immediately west of the narrow strip of the Spearfish sandstone, the Jurassic beds dip at a considerable angle, in a general westerly direction, but elsewhere the angle of the dip is low, and to the southwest.

The Sundance formation is about 200 feet thick, and is composed mainly of buff sandstones. The base of the formation, as exposed just west of the narrow strip of the Spearfish already referred to, consists of about 140 feet of buff to nearly white sandstone, here and there flecked with red. The rocks are in part massive, but where weathered they exhibit a generally thin-bedded structure. They are of variable grain, and are in part clayey. The upper 60 feet of the formation consists of a variable amount of more or less slabby sandstones with interbedded clays. A typical marine Jurassic fauna was found in the sandstones of this formation northeast of Cassa.

Morrison clay.[1]—Lying over the rocks of the Sundance formation are about 100 feet of massive shales or hardened clays, of various colors — green, purplish, reddish, light and dark gray to nearly black — with one or more thin beds of a moderately hard, compact, light-grayish limestone. This formation outcrops extensively in Wyoming and Colorado and yields many fossil bones of great saurians of the so-called "Atlantosaurus" fauna, the Como stage of central Wyoming. The beds are believed to be of fresh-water origin.

CRETACEOUS PERIOD.

Dakota sandstone.—Next above the Morrison clay are sandstones with several beds of shale and clay. The thickness of the exposed rocks is between 250 and 300 feet, the individual beds of sandstone ranging from about 2 feet to about 75 feet. They are in part hard and massive, cemented with silica into a quartzite which breaks into large, angular blocks, and range from that to soft and easily eroded rocks. Many of the sandstones show distinct bedding, and a few of them exhibit cross bedding. Several present ripple-marked surfaces. In color they are buff, light gray, brownish red, or nearly white, the last frequently tinged pink or reddish. In the upper part of the formation are one or more beds containing thin, platy concretions of ironstone. The beds of clay or shale occurring with the sandstones are from 2 to 8 or 10 feet in thickness, and of reddish, yellowish, or grayish color. In addition to the rocks described, there was seen at one point, about 85 feet above the base of the formation, a very thin bed (3 inches thick) of a rather fine-grained conglomerate.

The outcrops of these rocks are wholly confined to the northwest corner of the quadrangle, and here mainly to the dissected plateau already described as occurring north of Cassa. The formation as a whole dips at a low angle in a southwesterly direction. Owing to their generally resistant character, the rocks tend, wherever they have been deeply eroded, to form abrupt cliffs, the most pronounced of which are where the North Platte has cut through to the softer beds of the Morrison and Sundance formations below, the maximum height of these cliffs being about 400 feet.

In his report on the geology of the southern half of the Black Hills,[1] N. H. Darton has subdivided the corresponding series of rocks into the Lakota, Minnewaste, Fuson, and Dakota formations, the first probably belonging to the Lower Cretaceous and the last to the Upper Cretaceous, the other two being of doubtful age. While it is possible, and even probable, that the lower part of this series of rocks corresponds to the Lakota (Lower Cretaceous) of the Black Hills, no formation corresponding definitely to the Fuson or Minnewaste was observed, so that the line of division between the Upper and Lower Cretaceous rocks (if the latter are represented) can not be drawn, except arbitrarily. For this reason the rocks have been mapped without subdivision.

Graneros formation.—Lying conformably upon the Dakota sandstone is a succession of beds which are believed to correspond to the Graneros formation of the Black Hills and elsewhere. They are found in the northwest corner of the quadrangle, near the southern margins of the Dakota sandstone, and form a small mesa on the Dakota plateau. The thickness of the beds as exposed in the quadrangle is about 120 feet, which is probably only a fraction of the whole. They consist of about 100 feet of dark-colored shales, capped by about 20 feet of massive sandstones. The sandstones are rather fine grained, and buff to nearly white in color. The upper 20 feet of the shales are light gray, the remainder being black, or nearly so. The shales are fine grained and soft, and on weathering readily break into thin flakes. In their lower part they contain fine-grained, calcareous concretions, only fragments of which were seen at the surface. Most of these fragments are long and needle-like, and some show well-developed cone-in-cone structure.

EOCENE PERIOD.[2]

Chadron formation (*Oligocene*).—At a low level in Goshen Hole there is an exposure of the Chadron formation which in this quadrangle occupies about 15 square miles. It is the lowest member of the White River series, and lies on the Laramie sandstone, which outcrops a short distance east of the quadrangle. The formation is composed of clays, sands, and sandstones of various colors. Section 1 on Columnar Section sheet 1 represents the principal features of its stratigraphy.

There is some uncertainty as to the upper limit of the formation, and possibly the upper nodular clay should be excluded, as the calcareous nature of its upper part suggests that it may be a representative of the limestone bed which has been included in the basal portion of the Brule formation in other regions. The Chadron formation is characterized by the occurrence of bones and teeth of *Titanotherium*, an animal which was

[1] Since the above section was written, new evidence makes it appear that the Spearfish sandstone possibly should be referred to the Permian rather than the Triassic.

[1] This formation has until recently been considered Jurassic, but later fossil evidence makes it seem probable that it belongs to the Lower Cretaceous.

[1] Twenty-first Ann. Rept. U. S. Geol. Survey, Part IV, 1901, pp. 491-599.

[2] The description of Eocene and Neocene deposits is by N. H. Darton and C. A. Fisher.

about the size of an elephant. The teeth of this creature occur abundantly in the different beds, especially on the surface of the lower clay. The highest bed in which *Titanotherium* remains have been observed here is the lower part of the upper sandstone. There are many local variations in the beds, especially in the sandstones, which occur chiefly in narrow, meandering channels trending east-northeast. As the sandstones are hard, they give rise to ridges, which are usually from 10 to 15 feet high and from 20 to 30 feet wide in the case of the two upper sandstones, and very much smaller in the lower bed. The channels are eroded in the clays, and present considerable irregularity of depth and of form. Some of them exhibit branches. The sandstones, which are characterized by a greenish-gray color, are coarse and are cross bedded. One of the most conspicuous ridges rises on the east side of Cherry Creek a short distance south of Doty's Ranch, and extends, with a serpentine course, a half mile east-northeast. Its height averages 25 feet. Other ridges rise at intervals in the plain to the south, notably in secs. 21, 26, 27, 33, and 34, T. 24 N., R. 64 W.

The pink clays in the middle of the formation generally have a paler color than those of the Brule formation, and all the Chadron clays are of the nature of impure fuller's earth. At many places they give rise to miniature badlands.

Brule formation (*Oligocene*).—The middle slopes of Goshen Hole are composed of the Brule formation, which consists of pale-pink or flesh-colored massive clay with occasional lens-shaped masses of sandstone. Its thickness averages 250 feet. In portions of its area it is eroded into badlands, a feature which is characteristic of the formation. In section 2 on Columnar Section sheet 1 the characteristics of its lower beds are shown. On Columnar Section sheet 2 are presented some typical features of the stratigraphy of the formation, mainly of its middle and upper portions. These sections begin with the western portion of the area near Lakeview, and are arranged in regular succession to the eastward. It will be seen from the sections that the formation presents many stratigraphic variations, mainly in the local lenses of sandstone and the thin beds of volcanic ash. There is some uncertainty as to the precise limits of the top of the formation throughout the area, and apparently at some points there are beds of passage into the overlying Arikaree formation. Usually there is a strong contrast in the appearance of the beds above and below the line shown in the sections as defining the top of the formation, and in the cliffs north and northwest of Doty's Ranch there is a fairly definite unconformity by erosion with overlying deposits of coarse materials at this horizon. To the south the overlying beds (supposed Arikaree) are pinkish clays, but they are nodular, and differ much in appearance from the underlying massive pink clays of the typical Brule. Southwest of Lakeview the upper portion of the Brule formation is in part sandy and shows some concretions which are not typical, but apparently they are at the same horizon as the massive clays northeastward. Section 13 is from an outlying hill or ridge which is capped by 8 feet or more of conglomeratic sandstone. The bed appears to lie within the Brule formation, together with other sandstone caps on the low ridge to the northwest; but probably it represents the basal member of the Arikaree formation, and it is so shown in the columnar section. The underlying pink clay is here 200 feet thick and extends down to the upper beds of the Chadron formation. Thin beds of volcanic ash occur in the Brule formation, one of them attaining a thickness of 6 feet just east of Lakeview. This bed is shown in section 10, and appears to be the same as the bed shown in section 4, the upper bed in section 5, and the lower bed in section 2; but owing to lack of outcrops the question of continuity could not be determined.

Fossil bones occur frequently in the Brule clay and sometimes in the sandstones; they are typical middle White River or Oligocene forms.

NEOCENE PERIOD.

Arikaree formation.—The Arikaree formation covers about two-thirds of the quadrangle, the Cretaceous and older formations rising out of it, as an island, to the north, and the underlying Oligocene deposits being bared in the Goshen Hole depression. It not only lies against the ranges of older rocks to the north, but it occupies valleys in them, lying on an irregular surface carved in granites and schists, limestones and sandstones. To the southeast it overlies the Brule formation in regular though probably somewhat unconformable succession. Its full thickness is not exhibited in the quadrangle, though the exposures indicate a thickness of more than 700 feet.

The formation consists mainly of fine sand containing characteristic layers of hard, fine-grained, dark-gray concretions, often formed of aggregations of long, irregular, cylindrical masses, which have been called "pipy concretions." These concretions vary in thickness from a few inches to several feet. They have a very uniform trend, in an east-northeasterly direction. A single layer of these concretions is often many square yards in area. The sands in which they are embedded are very light gray, almost white, in color, and are friable to fairly compact, usually the latter. Some of the sands are more or less argillaceous. Elsewhere, east of the quadrangle, *Dæmonelix*, or "Devil's corkscrew," in its various forms occurs in this formation, but no specimens were found within the quadrangle. The sandstones of the Arikaree deposits contain a large amount of intermingled volcanic sand and dust. At the base of the Arikaree formation, which is extensively exposed about the margin of the Goshen Hole depression, there is seen to be considerable diversity in the character of its earliest deposits (see sections on Columnar Section sheet 2), and there is some uncertainty as to the dividing line between it and the Brule formation. The more conspicuous features are shown in section 3. From a short distance the bluffs usually show a sharp distinction between the Brule clay below and the Arikaree beds, with their more sandy beds and pipy concretions, above, but on closer inspection the materials in a portion of the region exhibit some evidence of transition. North and northwest of Doty's Ranch there intervene coarse sandstones which suggest, by position and appearance, the Gering formation of the Scotts Bluff and Camp Clarke quadrangles (see sections 9 to 14); but it could not be ascertained whether they constitute a separate formation, or even whether they form a basal member of the Arikaree formation. As, however, they appear to merge into that formation, they are provisionally included in it. Farther south and west these sandstones thin out and give place to others, which occur at intervals near the base of the bluffs and appear to be included entirely in the Brule formation, as shown in sections 4, 5, and 9. The base of the Arikaree in that region seems to be represented by pale-pinkish sandy clays containing nodules that suggest incipient development of pipy concretions. These clays are sharply separated from the underlying clay, which is of a typical Brule character, except for a short distance south of Lakeview, where the upper beds of the supposed Brule formation are more sandy and contain some concretions. The overlying paler pink clay with nodules, described above, has a thickness of 200 feet and merges upward into typical gray sands and soft sandstones, all with pipy concretions. Section 3 shows the succession of beds on the high cliffs here, where several hundred feet of the Arikaree deposits are exposed. It is a continuation of section 4, on Columnar Section sheet 2.

Though the beds are relatively soft and easily eroded, they tend to form abrupt cliffs, owing to their generally compact character and to the presence of these concretions. To this formation belong the characteristic forms in the southern half of the quadrangle, already described under "Topography," the broad, nearly level stretches frequently surmounted by higher mesas and generally bordered by abrupt sinuous cliffs. Just south of the northern margin of the quadrangle, and 6 miles north of west of 4 J Ranch, is a rugged butte of the Arikaree, several hundred feet in height, capped by a bed of sandstone having pronounced columnar structure (see fig. 1, on Illustration sheet).

PLEISTOCENE PERIOD.

Alluvium.—Some of the larger streams of the quadrangle (particularly North Platte and Laramie rivers and Cottonwood and Horseshoe creeks), in their meanderings in the soft Arikaree deposits, have developed bottom lands along their courses. These bottom lands are covered for the most part with gravel and sand, with here and there a comparatively thin mantle of silt. Some of them have a width of a mile or more, and they constitute a considerable part of the agricultural land of the quadrangle.

In addition to these deposits bordering the present larger streams, there are older alluvial deposits at a number of higher levels. The broad, level uplands adjacent to the present stream courses in the Arikaree formation are nearly everywhere covered to a greater or less extent with such deposits, as are also the tops of many of the flat hills or mesas projecting above them (see fig. 2, on Illustration sheet). These deposits consist, as a rule, of gravels covered with a variable amount of sand and silt. The higher deposits generally contain a larger proportion of gravel and a smaller proportion of sand and silt than the lower deposits, the finer materials having been washed away from the higher and generally narrower areas. These deposits (as will be explained more fully under "Geologic history") mark the bottom lands of older and broader valleys, formed at higher levels than those of the present time, the highest deposits being the oldest. They were doubtless more widespread at one time than at present, the oldest deposits having been washed away in many localities. In some places mere remnants are now found, occurring as scattered pebbles. From this they range to heavy sheets several feet in thickness. The gravels occur in many places where their presence is not at first suspected because they are covered by sand and silt and can be seen only along the edges of the cliffs, where the deposits have been cut into by streams. This is the case with much of the gravel covering the broad Arikaree uplands adjacent to the present stream courses.

These alluvial deposits occur mainly on the Arikaree formation, though occasionally they are found resting on the older and harder rocks. They occur in several places on the Dakota plateau in the northwestern part of the quadrangle, also resting on the Carboniferous rocks just north of Fairbank, about 200 feet above the floor of Hartville Canyon, and on the flat-topped divide between Hartville and Whalen Canyon east of Sunrise. There is also one point—in the gorge of the North Platte in the northwestern part of the quadrangle—where gravels are seen resting on a short spur of the Morrison clays at an elevation of about 100 feet above the river.

The material of these deposits, being derived by the streams from the various rocks through which they flowed, varies considerably at different points; and the locally derived gravels differ from those brought from a distance in being somewhat more angular. The gravels comprise pebbles of granite, gneiss, schist, quartzite, limestone, sandstone, quartz, chalcedony, and feldspar. These alluvial deposits rest unconformably upon the formations beneath them, and are probably all of Pleistocene age.

Soils.—The soils of the quadrangle are thin, owing largely to the aridity of the climate. Except for the alluvial deposits described in the last section, the soils are closely related to the underlying rocks from which they are derived by weathering. The Arikaree is the only formation presenting extensive surfaces sufficiently level for cultivation; but as these rocks do not weather readily, their own soils are everywhere thin, and the soils mantling some of the more level stretches of this formation are derived chiefly from the later alluvial deposits spread over it. Even with this mantle of alluvium the Arikaree supports only a scattered natural growth of grasses and other low plants, and most of it is suitable only for grazing. The most favorable portion of the Arikaree uplands, as regards soil, is in the southwest corner of the quadrangle, in the alluvium-covered area about Wheatland; but even here extensive irrigation is necessary for raising crops. The other Tertiary formations have practically no soils. In the formations older than the Tertiary there are small areas of good soils, but much of the topography is so rugged, and water is so scarce, that the region generally is suitable only for grazing.

GEOLOGIC HISTORY.

The oldest rocks of the quadrangle are those of the Whalen group, and the decipherable history of the region therefore begins with the deposition of the sediments represented by these rocks. These sediments consisted of clays, sands, and calcareous muds, deposited in the Algonkian seas, which then covered the region. The source of the sediments is not known, but they must have come from the wearing down of a considerable land mass then existing in the neighborhood of this area.

Since limestones and clays are generally indicative of deep-water conditions, while sandstones show shallower waters, the presence of all three rocks in this series would indicate such movements of the sea bottom on which they were laid down as to give now shallower and now deeper waters over the whole area. At some time following the Algonkian period of sedimentation these rocks were folded and crushed, and intruded by the igneous rocks which we now find associated with them, and of which the coarse granite is the oldest, it and the schists having been penetrated by the finer-grained granites and the dikes of aplite and pegmatite. In the course of these changes the rocks of the Whalen group were metamorphosed, being altered from shales, sandstones, and limestones to schists, quartzites, and more highly crystalline limestones. The former sea bottom now became a land area, and a long period of erosion followed. Whether this immediate region again became an area of sedimentation before the deposition of the Carboniferous sediments can not be stated, as no intermediate deposits are found. In any case the total amount of erosion must have been great, since it was sufficient to expose at the surface the granites, which are formed only as deep-seated rocks; and in order that this amount of erosion should take place, a correspondingly great elevation of the land must have occurred, though the rate of this elevation was doubtless slow. The land forms during a part of this time were probably generally rugged, since both the metamorphic and the igneous rocks are resistant, and to-day give rise to the most rugged topographic forms of the quadrangle. Near the close of the interval of erosion just preceding the Carboniferous period, it is probable that the land forms had all been greatly reduced and that the surface was gently rolling.

Near the beginning of the Carboniferous period, the land was slowly depressed, and the sea once more covered the area. As the land was submerged it was planed off by the continued cutting of the waves along the shore line, and thus was formed the surface on which the basal quartzite of the Guernsey formation rests. This was composed of the coarser quartz sands and pebbles deposited along and near the shore line. After this the land was further depressed, and in the deepened waters were deposited the limestones lying above this basal quartzite. Then followed fluctuations in the position of the land, and consequently in the depth of the coastal waters, with probably, also, local variations in the amount and character of the sediments furnished by streams from the land and by waves along the shore, resulting in the succession of sandstones and limestones of the Guernsey formation. Later a slight elevation of the region above sea level resulted in the erosion which gave rise to the uneven surface underlying the red quartzite at the base of the Hartville formation. This period of erosion was geologically very short and was succeeded by a resubmergence of the land, which appears to have continued without interruption during the rest of the Carboniferous period. During this time were deposited the sediments composing the beds of the Hartville, Opeche, and Minnekahta formations. The Carboniferous rocks above the red quartzite and below the Spearfish sandstone are mainly limestones, indicative of deposition in deep waters, though there are occasional intercalated sandstones, showing fluctuations in the relations of sea and land.

During the succeeding epoch, though the region remained covered with water, it is believed that the conditions were somewhat changed, the waters, though still widespread, being now enclosed so as to form great inland seas of moderate depth, in which were laid down the sandy or clayey deposits of the Spearfish formation (Red Beds). In some of the areas the waters became concentrated, leading to the chemical precipitation of the gypsum which farther north forms such a marked feature of these beds. These gypsum deposits are generally characteristic of the sediments of this epoch throughout the Rocky Mountain and Great Plains provinces, over which similar conditions prevailed at this time. The red color of the clays and sands is also a constant character of these sediments, and is evidently original, since it extends throughout the thickness of the formation, below as well as above the level of surface oxidation, as shown both by deep borings and by surface exposures.

After the deposition of the red sandstones of the Spearfish formation the seas became open once more, though still of only moderate depth, and at this time were deposited the sandstones and clays of the Sundance formation. The ripple-marked surfaces of these sandstones and those of the Spearfish formation are evidence of comparatively shallow waters during both Triassic and early Jurassic times in this region; while the Morrison clay with its interbedded limestone points to deeper water during the later Jurassic. These conditions also were widespread, as the Morrison formation extends from Montana to Oklahoma.

Following an interval of erosion, indicated by a general unconformity between the Morrison clays and the overlying Cretaceous rocks, sedimentation continued, with some slight oscillations of the land, during the early part of the Cretaceous period. The early Cretaceous seas were shallow on the whole, and in their waters were laid down the ripple-marked sandstones of the Dakota and Graneros formations. The shales and clays found with these sandstones would appear to indicate either variations of water depth or else a variation in the material furnished from the land; or they may be the finer portions of sediments the coarser parts of which were deposited elsewhere as sandstones by the shifting currents of these Cretaceous seas. Only a part of the Cretaceous sediments are represented in this quadrangle; other formations of this age at one time existed here, but they have been wholly removed by erosion. As shown elsewhere, where these later formations are found, the Cretaceous seas continued to cover this region long after the deposition of the Dakota and Graneros beds. At times the area was deeply submerged, and again the waters were of only moderate depth.

Toward or at the close of the Cretaceous period the sediments which had been accumulating almost without interruption since early Carboniferous time were gently folded and elevated above sea level. The open folds seen in the Cretaceous and pre-Cretaceous rocks of the quadrangle, shown in the sections on the Structure Section sheet, were formed at this time. A prolonged period of subaerial erosion followed, during which several thousand feet of rock were removed from the surface of the land, though the amount of this erosion differed in different parts of the quadrangle. On the west, only the rocks above the Graneros have been removed, while on the eastern side of the quadrangle all the sedimentary rocks have been worn away in places, uncovering the metamorphic and igneous rocks below them.

It is probable that during this long period of erosion the minor stream courses were shifted more or less to meet the changing conditions as the rocks of the different formations were successively exposed through erosion. Toward the close of the period, the contrasts in the topography were greater than at present; for while the hills were not much, if at all, higher than now, many of the valleys were considerably deeper than we now find them. It was at this time that much of the present topography in the Cretaceous and older rocks was developed. The Carboniferous upland was laid bare and its more open valleys were produced, the anticline on its eastern margin was cut through by streams, and the cliffs west of Waterhole Ranch were formed; Haystack Range and the granite hills north of it were sculptured with almost their present detail; Whalen Canyon and Hartville Canyon were carved, both deeper than at present, and the streams of both, then as now, flowed to the south. The Dakota plateau extended as a tongue of land to the southwest, with an open valley on the southeast, in the region of Cassa, and another on the northwest, in the corner of the quadrangle.

The course of the main drainage line at that time did not conform to that of the North Platte as it is to-day, and the gorges through the Dakota sandstone and the rocks of the Hartville formation had not been cut as we now find them, except at one point, southeast of Cassa. Here, where the present gorge of the North Platte turns to the south, it is met by a large open valley, trending westerly. At the close of the period of erosion just considered, the stream occupying this valley did not terminate where it does now, but continued toward the northwest and flowed out into the valley near the present site of Cassa. The western end of the valley then occupied by this stream now forms a part of the gorge of the North Platte, the latter, however, flowing to the east, while the former stream flowed westward. This part of the gorge and the old valley to the east were at that time developed much as at present, the width being nearly the same, while the depth was a little greater.

A period of extensive sedimentation in fresh waters followed, during which were laid down the deposits a part of which are represented by the Oligocene and Neocene formations of the Hartville quadrangle. The area of deposition of this series extended across eastern Colorado and Wyoming and western Nebraska and South Dakota, and probably also farther northward, for similar deposits have been found in western Canada. It is probable that during the earlier part of this time short episodes of local lake deposition alternated with others of stream erosion and sedimentation. All the older formations of the quadrangle were probably completely buried by these Tertiary deposits, which now extend to within 250 feet of the highest points of the quadrangle. The original thickness of these deposits is not known, and can only be inferred from what remains of them to-day. In this quadrangle they have an observed vertical range of about 1200 feet.

The Oligocene and Neocene waters finally drained off, and then began the present period of erosion, during which a considerable part of the Tertiary deposits have been removed, and some of the underlying older rocks have been once more laid bare. As these areas with their older drainage lines have been exposed, the streams have sought again their former channels.

In the process of removing these deposits, the larger streams have meandered and cut back their cliffs, forming broad plains, strewn with river sediments; and the process, being repeated at different levels, has resulted in terraces, each lower than the last, the successive valleys being each narrower than the preceding, the present valleys the narrowest of all. Thus a rude series of gravel-capped terraces has been left to mark the levels of the earlier valleys. These now form the broad, level uplands of the Arikaree formation, with their higher, flat-topped mesas, many of which are gravel capped, showing them to be remnants of still older valley floors. These terraces or former valley floors are also found in a number of the old canyons, as, for example, the terrace forming the greater part of the floor of Whalen Canyon, and the terraces bordering Hartville Canyon south of Hartville. In their wanderings the streams have swept over nearly all parts of the quadrangle, and old stream gravels are now found not only in elevated positions but several miles distant from any of the present streams.

Casebier Hill is an example of these outlying gravels, as well as of the protective action of the gravel caps, to which some of the higher hills and mesas composed chiefly of the Arikaree formation owe, in part at least, their persistence. Loose gravels readily absorb much of the water that falls on them; further, they interfere with the flow of surface waters, and on account of their hardness and the weight of the pebbles, they are not readily removed by the smaller surface streams. Therefore such gravels capping a comparatively soft rock protect it to a greater or less extent from active surface erosion.

In carving its channel the North Platte, for a part of its course, cut entirely through the soft Arikaree deposits, reaching the harder rocks of the Dakota and Hartville formations beneath; it then began to cut into these resistant rocks, and having made a beginning, the stream has been compelled, by the hard walls which confine it, to continue its cutting along the lines it was following when it first entered these formations. Its present meanders are therefore inherited from its earlier meanders in the Arikaree formation. Since the resistant character of the rocks has prevented any appreciable amount of lateral erosion, the stream has cut for the most part vertically, thus forming the gorges which mark its course.

ECONOMIC GEOLOGY.

IRON ORE.

Iron ore (hematite) is the most important economic product of this region. It is found in the rocks of the Whalen group, within a rather limited area on the west side of Whalen Canyon, beginning at a point about a mile south of Frederick and extending southwesterly a little over 4 miles. The town of Hartville marks its western limit, the southern limit being about a mile and a half south of Sunrise. The area of paying ore is still smaller, being confined, so far as known, to the immediate vicinity of the Sunrise iron mine and to a narrow strip running to the southeast and northeast of this, across the hills to the western slopes of Whalen Canyon. The iron ore occurs both in the limestones and in the schists, being developed mainly along and not far from the contact between them. This contact runs from just west of the Sunrise iron mine southerly, then southeasterly to the west side of Whalen Canyon. North of Sunrise the rocks of the Whalen group pass beneath the Guernsey formation. It is probable, however, that the line of contact runs northerly for a short distance and then northeasterly until it emerges again on the west side of Whalen Canyon. The iron ore appears to occur in scattered irregular pockets in the limestone, and in the schist in long lenses of variable size, from a fraction of a foot to 100 feet or more in width, the larger ones probably extending for considerable distances. The main body of ore occurs in the schist not far from the eastern border of the limestone. The information at hand is not sufficient to decide whether there are several ore-bearing horizons or a single horizon repeated by folding.

The deposits in the schists are in general more extensive and of better quality than those in the limestones, and constitute the paying ore in the region just described. This ore consists of two varieties of hematite, one soft and the other hard. The former is a generally schistose, fine-grained ore, light red in color, and easily soils the fingers. This variety is commonly known as "paint ore." The harder variety is of a dark bluish-gray color, from which it receives the common name of "blue ore." It is fine grained and compact, with a rather smooth, even fracture. Of the two varieties the harder is the more valuable. The hematite is occasionally associated with a small amount of copper ore.

Though much prospecting has been done, in the course of which much good ore has been uncovered, there is at present but one mine in active operation, that of the Colorado Fuel and Iron Company, at Sunrise. The mine is an open cut in the hillside, to the level of the valley floor (see fig. 6, Illustration sheet). The looser surface material is in a condition to be handled as it lies, but the harder ore beneath it requires blasting. The ore is taken out with a steam shovel, which loads it directly into the cars that carry it to Pueblo, Colo., for smelting. At the time it was visited the mine was shipping about 400 tons of ore daily, and it was expected that with the addition of a second steam shovel the output would soon be increased to 1000 tons a day. The ore shipped from this mine is of high grade, averaging about 62 per cent of metallic iron, with about 2½ per cent of silica, and practically no phosphorus or sulphur. The maximum iron content is about 66 per cent, and the lowest silica about 1 per cent.

In addition to these deposits in the rocks of the Whalen group, there are small local deposits of coarse, reddish conglomerate, containing numerous well-rounded pebbles of hematite, besides pebbles of quartz (up to 6 inches or more in diameter) and occasional pebbles of schist. These conglomerates were noted at a number of points, and in all cases they were found to rest on the limestones of the Whalen group, at the base of the basal quartzite of the Guernsey formation, to which they probably belong. The occurrence of these pebbles of hematite, together with the fact that, so far as known, the main deposits are limited to the rocks of the Whalen series, and do not extend into those of the Guernsey formation above, indicates that the mineralization which gave rise to the iron ores took place before the rocks of the Guernsey formation were laid down.

COPPER.

In addition to the iron, the rocks of the Whalen group and the Guernsey formation have yielded more or less copper ore, though at the time the region was visited by the writer little more than prospecting was being done. At the Welcome mine, at the eastern base of the granitic hill northeast of Frederick, ore was being taken out for future shipment. This is a banded, bronze-colored ore, consisting largely of pyrrhotite, with more or less intermingled chalcopyrite. There has been much prospecting for copper, not only in Haystack Range, but also in the hills on the west side of Whalen Canyon, between Hartville and Guernsey; and at one or two places, besides the mine just mentioned, the indications are favorable for paying ore. The most favorable of the copper prospects are located on mineralized bands in the schists or quartzites, the mineralization, in the case of the Welcome mine at least, being in the nature of a replacement deposit.

Copper mining was formerly carried on more extensively than at present. One of the earlier mines, situated about a mile north of east of what is now Guernsey, is said to have yielded about $60,000 worth of ore from a replacement deposit in the massive gray limestone of the Guernsey formation. The early surface workings of the Sunrise mine also yielded a considerable amount of copper. The smelter built for this mine, near Fairbank, was subsequently burned.

Silver and gold have been reported as occurring with the copper ores in Haystack Range, but no reliable information could be obtained on this point.

LIMESTONE.

Limestone is found in abundance in the Guernsey and Hartville formations and to a less extent in the Whalen group. The limestone of the latter formation, owing to its generally schistose character and to the thin quartz seams which everywhere penetrate it, is not adapted for use either as a building stone or for making quicklime. The Guernsey and Hartville formations, being composed in large part of massive limestones, offer a practically inexhaustible supply of that rock. The limestones as a whole are nonmagnesian in character. So far as known these rocks have not been quarried for building purposes. They have been quarried near Hartville and burned for quicklime, and they would make a suitable flux for the reduction of the iron ores which are found in the region.

Onyx marble.—Here and there in the limestones of the Hartville formation are found small caves or cavities formed by solution; and in these, coating the walls, or as rude stalactitic or stalagmitic growths, are secondary deposits of a banded limestone of the variety known as onyx marble. The selected material is homogeneous, light colored, and generally marked with narrow bands of white and various shades of brown, or of white and pale green. On account of the comparative coarseness of the grain and the slight contrast in color (which are common characters of cave onyx), the demand for this material would probably be small. A number of openings have been made in these deposits at different points within a radius of 2½ miles to the north, west, and southwest of Hartville, and 160 acres in claims have been staked out; but at the time the region was visited none of the material had been put on the market. As the area already explored for this product embraces but a small part of the Hartville formation, and as similar deposits are likely to occur in any of the limestones of this formation, it is probable that only a small proportion of the material has as yet been brought to light.

SANDSTONE.

Sandstones are found in the Guernsey, Hartville, Opeche, Spearfish, Sundance, and Dakota formations, and also in the Tertiary deposits. Those of the Dakota are best adapted for building purposes. Those of the Opeche and Spearfish formations and of the Tertiary rocks lack strength and durability, and this is probably also the case with much or most of the sandstone of the Sundance formation. It is possible that some of the sandstones of the Guernsey and Hartville formations might be available for building purposes. They are for the most part light colored, gray and buff, and are generally of medium to fine grain, and more or less firmly cemented with calcite. These sandstone beds, however, are not numerous, and are usually only from 3 to 5 feet in thickness. Further, the fact that they are interbedded with massive limestones would make them less accessible than the Cretaceous sandstones. The Dakota sandstones are generally massive, and the beds average between 10 and 20 feet in thickness. The grain is variable, as is also the texture. While one or two of the beds may approach quartzite in character, the majority have only moderate hardness. Their colors are probably permanent, and their strength and durability are attested by the abruptness of the cliffs which they form wherever they have been cut through by erosion. Sandstones from the same formation, in other localities, have been practically tested as building stones.

GRANITE.

It is possible that the granites of the northeastern part of the quadrangle might furnish a good quality of building stone. They are moderately coarse grained, and appear to be firm and durable.

Mica.—Some of the coarser pegmatites of the quadrangle contain sheets of white mica (muscovite) of considerable size, but so thin and scattered that their economic importance is likely to be small. The mica of these pegmatites was mined to some extent between fifteen and twenty years ago, and some of the product was shipped to the eastern markets.

Quartz and feldspar.—The large quartz and feldspar crystals found in these pegmatites might prove of value in the manufacture of glass and pottery.

GYPSUM.

As has already been mentioned, a white granular gypsum occurs in rather thin beds in the northwestern part of the quadrangle, in the lower portion of the Spearfish sandstone. This gypsum has been used locally, by a few settlers, for plaster.

FIRE CLAY.

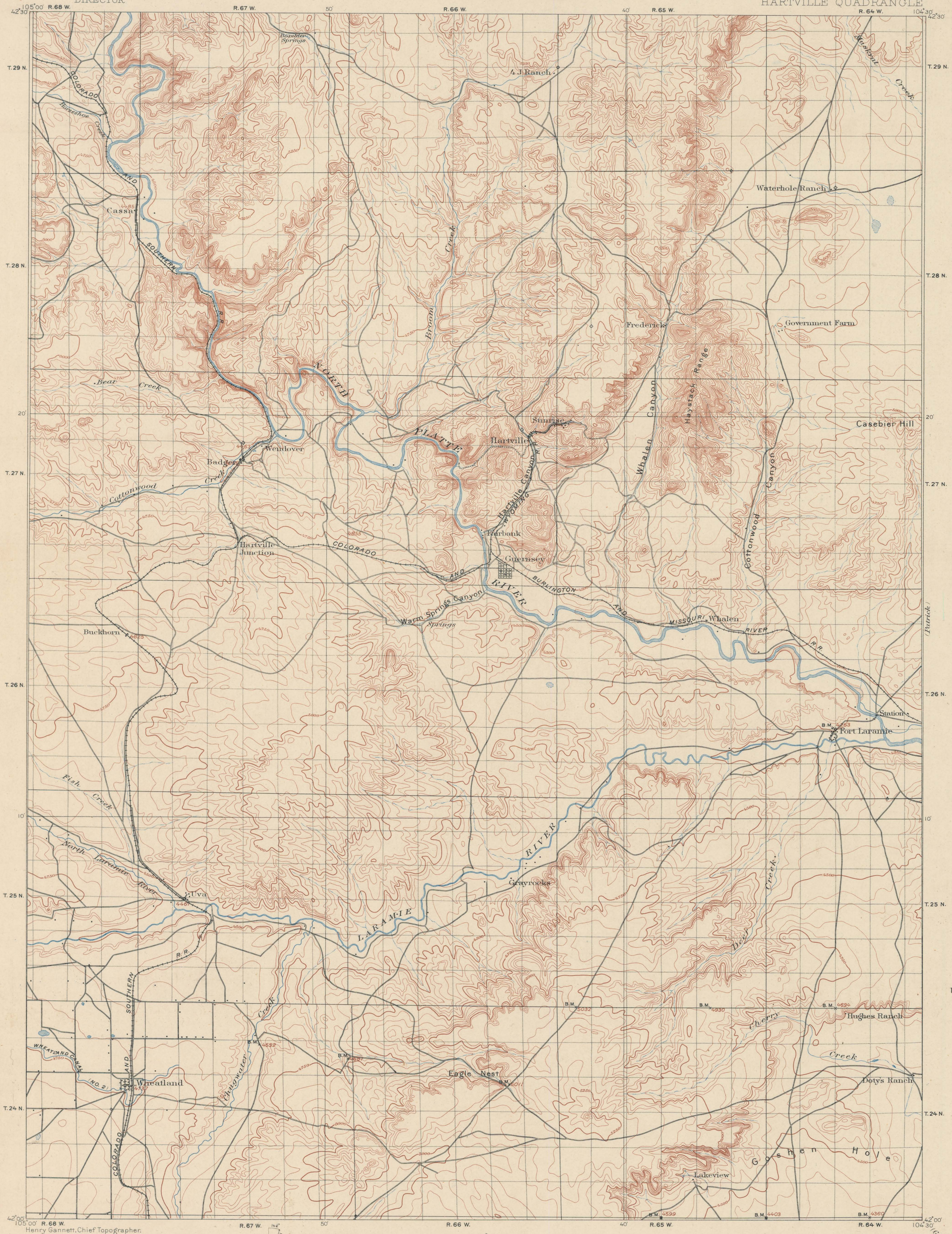
Where the Dakota and lower Cretaceous sandstones are exposed, along the eastern front of the Rocky Mountains, they contain a variable number of interstratified beds of clay or shale. In places some of these shales and clays are found to be refractory and to furnish fire clays of good quality. As this series of rocks occurs within the Hartville quadrangle, it is possible that some of the clays found here may prove to be of such a character.

June, 1901.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
DIRECTOR

TOPOGRAPHIC SHEET

WYOMING
(LARAMIE COUNTY)
HARTVILLE QUADRANGLE



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)*

Sand

DRAINAGE *(printed in blue)*

Streams

Intermittent streams

Canals and ditches

Lakes and ponds

Intermittent lakes

Springs

CULTURE *(printed in black)*

Roads and buildings

Private and secondary roads

Railroads

Bridges

Fords

U.S. township and section lines

Bench marks

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Topography by W. S. Post.
Surveyed in 1895.

APPROXIMATE MEAN DECLINATION 1900

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

Edition of Aug. 1902

(Goshen Hole)

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
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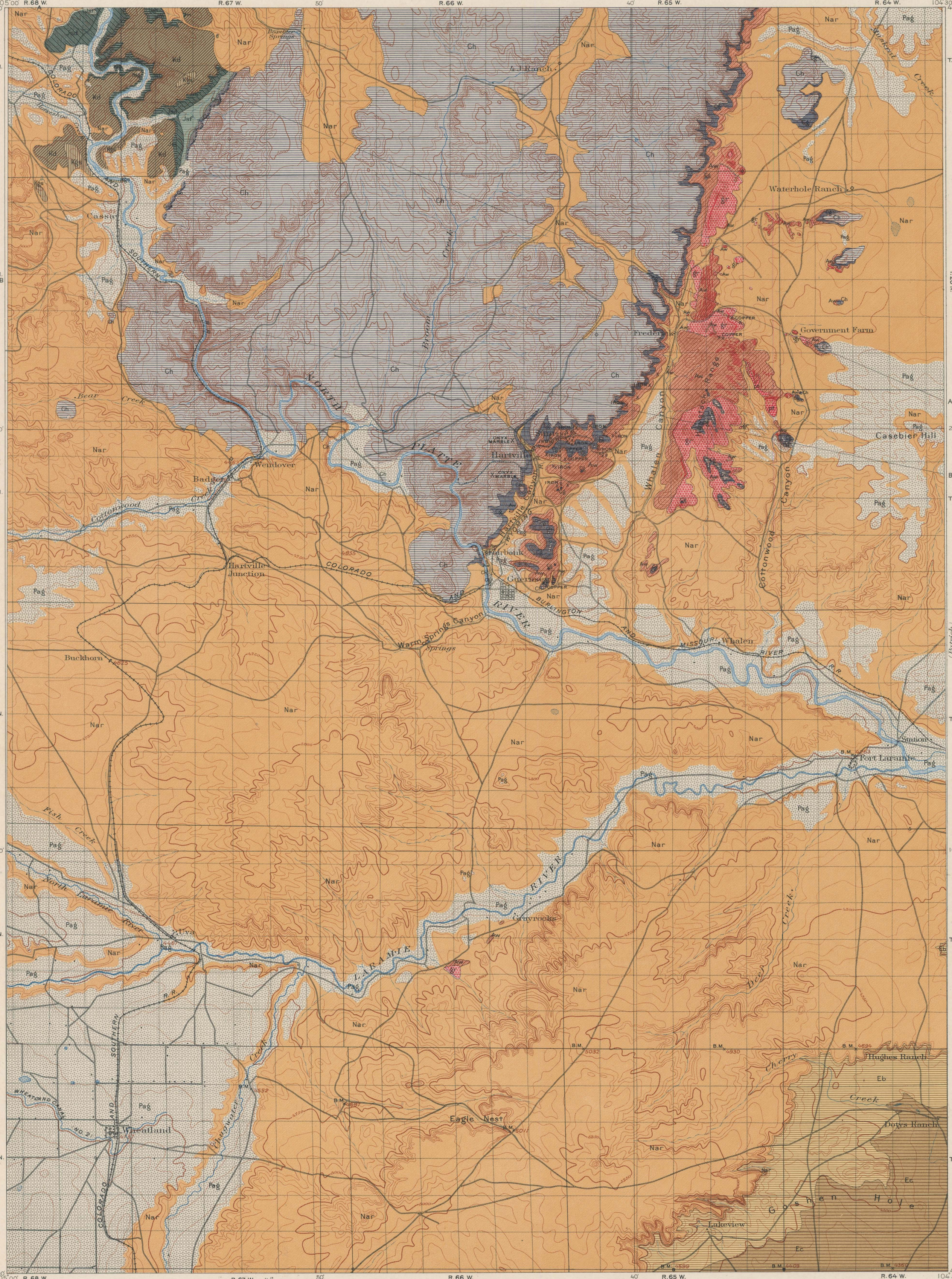
AREAL GEOLOGY SHEET

WYOMING
(LARAMIE COUNTY)
HARTVILLE QUADRANGLE



LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles)

PLEISTOCENE

- **Pag** — Alluvium and terrace gravels *(gravel, sand, and silt on old terraces and in recent stream bottoms of which only the larger areas are shown)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines)

NEOCENE — MIOCENE

- **Nar** — Arikaree formation *(white sand and soft sandstone with concretions)*

EOCENE — OLIGOCENE

- **Eb** — Brule formation *(flesh-colored sandy clay with sandstone layers)*
- **Ec** — Chadron formation *(green, maroon, and pink sandy clay and gray sandstone)*

CRETACEOUS

- **Kgs** — Graneros formation *(dark-colored flaky shale, containing calcareous concretions and some massive sandstone)*
- **Kd** — Dakota sandstone *(massive sandstone with thin beds of shale; possibly includes lower Cretaceous strata at the base)*

JURATRIAS — JURASSIC

- **Jm** — Morrison clay *(clay of various colors; green, purplish, reddish, light gray, dark gray, and nearly black)*
- **Jsd** — Sundance formation *(buff sandstone with interbedded clay near the top)*

JURATRIAS — TRIASSIC ?

- **Jsf** — Spearfish sandstone *(soft thin-bedded red sandstone; "Red Beds")*

CARBONIFEROUS

- **Cmk** — Minnekahta limestone *(very thin-bedded gray limestone)*
- **Co** — Opeche formation *(fine-grained red sandstone with some shale)*
- **Ch** — Hartville formation *(massive limestone with beds of sandstone and quartzite)*
- **Cg** — Guernsey formation *(limestone with some sandstone and quartzite)*

ALGONKIAN

- **Aw** — Whalen group *(quartzite, schist, and siliceous limestone, with some gneiss)*

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

ALGONKIAN ?

- **gr** — Granite *(large masses, intrusive in the Algonkian rocks)*
- **pt** — Pegmatite *(large masses, intrusive in the Algonkian rocks)*
- Dikes *(granite, pegmatite, and some aplite)*

⚒ Mines
X Prospects

Sections

Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Topography by W. S. Post.
Surveyed in 1895.

APPROXIMATE MEAN DECLINATION 1900

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

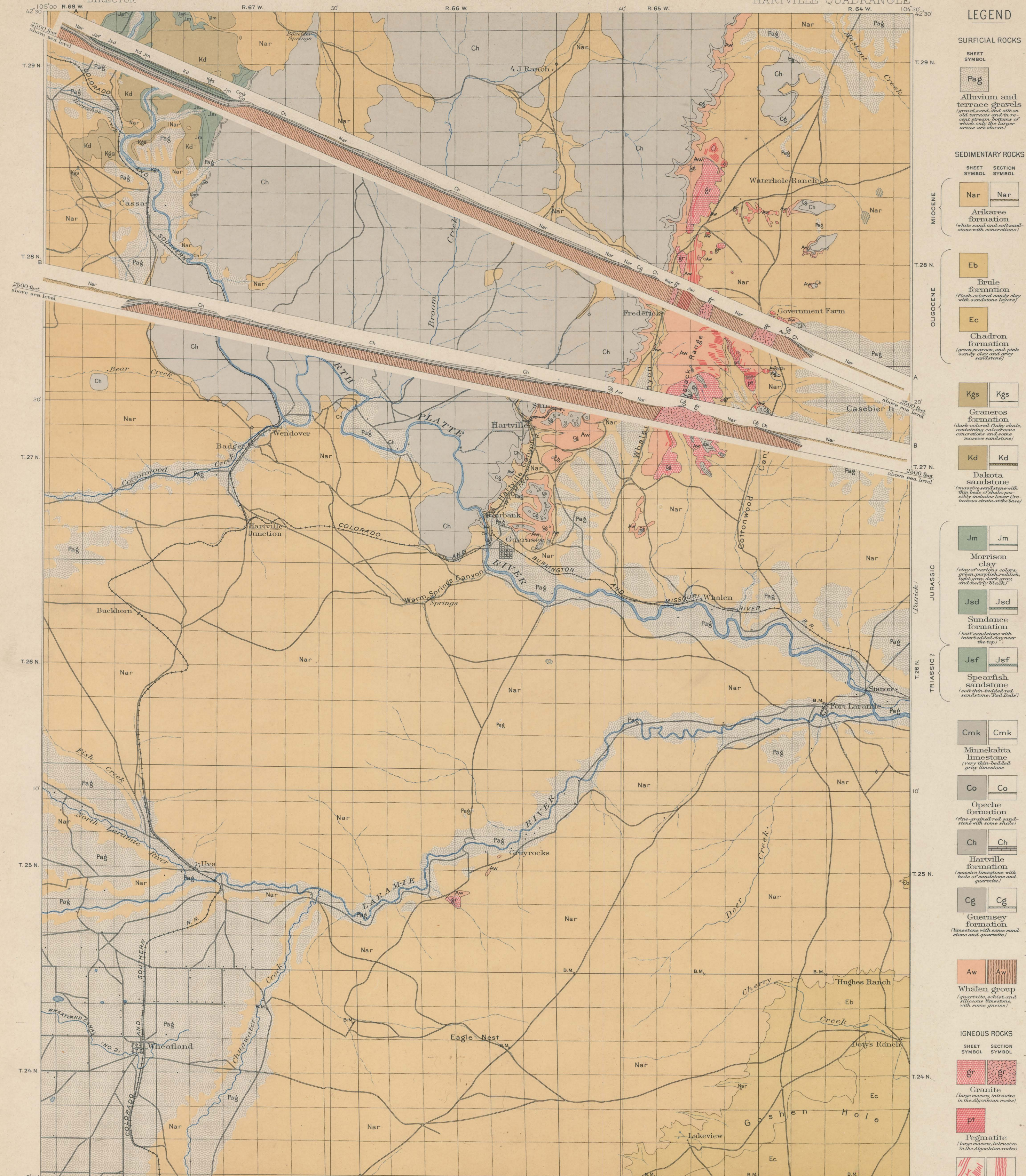
Edition of Sept. 1902.

Geology of Cretaceous and older rocks by W. S. Tangier Smith.
Geology of post-Cretaceous rocks by N. H. Darton, assisted by C. A. Fisher.
Surveyed in 1900 and 1902.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
DIRECTOR

STRUCTURE-SECTION SHEET

WYOMING
(LARAMIE COUNTY)
HARTVILLE QUADRANGLE



Henry Gannett, Chief Topographer.
Jno. H. Renshawe, Topographer in charge.
Topography by W. S. Post.
Surveyed in 1895.

Scale 1/125000
Miles
Kilometers

APPROXIMATE MEAN DECLINATION 1900

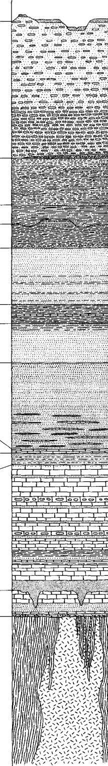
Edition of Nov. 1902.

Geology of Cretaceous and older rocks by W. S. Tangier Smith,
Geology of post-Cretaceous rocks by N. H. Darton; assisted by C. A. Fisher.
Surveyed in 1900 and 1902.

COLUMNAR SECTION SHEET 1

GENERALIZED SECTION OF THE ROCKS OF THE HARTVILLE QUADRANGLE.

SCALE: 1 INCH = 500 FEET.

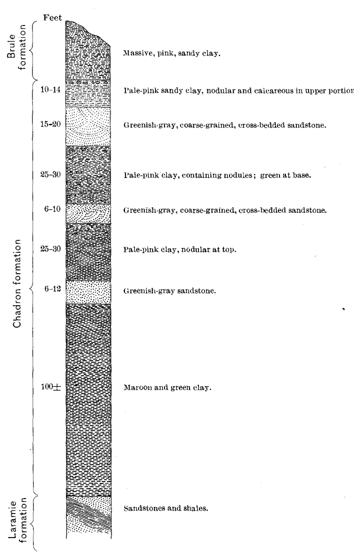
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in feet.	Character of Rocks.	Character of Topography.
PLEISTOCENE	Alluvium.	Pag		1-30	Gravel, sand, and silt.	Occupies valley floors and caps mesas and terraces.
NEOCENE	Arikaree formation.	Nar		700+ (30-40)	White sand and soft sandstone with pipy concretions. Gray sandstone and conglomerate.	Valleys of variable width, bordered by abrupt slopes; broad mesas, terraces, and extensive, flat uplands; and the upper portions of cliffs.
EOCENE (OLIGOCENE)	Brule formation.	Eb		250	Flesh-colored sandy clay with lenses of sandstone.	Slopes below cliffs of Arikaree formation and broad, shallow valleys separated by low, broad divides.
EOCENE (OLIGOCENE)	Chadron formation.	Ec		60+	Green, maroon, and pink sandy clay and gray sandstone.	Valleys.
	— UNCONFORMITY —					
CRETACEOUS	Graneros formation.	Kgs		120+	Gray flaky shale with concretions and massive sandstone near the top.	Mesas and hills with flat or gently sloping tops.
CRETACEOUS	Dakota sandstone.	Kd		250-300	Massive buff, gray, and reddish sandstone and quartzite with several thin beds of clay and shale.	"Hogback" hills with gentle slopes or flat-topped hills bordered by abrupt cliffs.
JURATRIAS — JURASSIC	Morrison clay.	Jm		100	Clay of various colors from green to purple and black, with a thin bed of limestone.	Slopes below Dakota sandstone cliffs, and valleys between.
JURATRIAS — JURASSIC	Sundance formation.	Jsd		200	Buff sandstone with interbedded clays near the top.	Slopes, especially at the base of Dakota sandstone cliffs; also valleys.
JURATRIAS — TRIASSIC ?	Spearfish sandstone. ("Red beds.")	Jsf		450	Dark reddish-brown, medium-grained, thin-bedded sandstone containing limestone lenses and thin sheets of gypsum in the lower portion.	Valleys and low saddles.
CARBONIFEROUS — PERMIAN ?	Minnekahta limestone.	Cmk		20	Gray to purplish, thin-bedded, platy limestone.	Summit and western slopes of low "hogback" hills.
CARBONIFEROUS — PERMIAN ?	Opeche formation.	Co		60	Bright-red, thin-bedded sandstone, with red, flaky shale.	Eastern slopes of Minnekahta limestone "hogbacks;" also valleys.
CARBONIFEROUS	Hartville formation.	Ch		650	Massive gray limestone, some beds containing chert nodules, with occasional beds of white, gray, buff, and red sandstone. Red shale and gray limestone. Red quartzite streaked with white.	Flat-topped hills with narrow canyons and open valleys. Upper portion of cliffs and flat or sloping tops of hills.
	— UNCONFORMITY —					
CARBONIFEROUS	Guernsey formation.	Cg		150	Conglomeratic quartzite with overlying sandstone and massive gray limestone.	
ALGONKIAN	Whalen group and intrusive granite.	Aw (gr)			Quartzite, schist, siliceous limestone, and gneiss. Large masses and dikes of granitic rocks intrusive in the sedimentary beds.	Rugged hills and slopes.

DETAILED COLUMNAR SECTIONS, HARTVILLE QUADRANGLE.

SCALE: 1 INCH = 50 FEET.

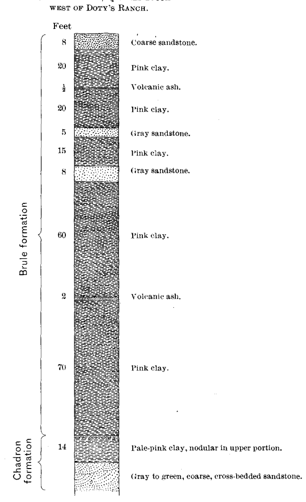
SECTION 1.

Chadron formation, western portion of Goshen Hole.



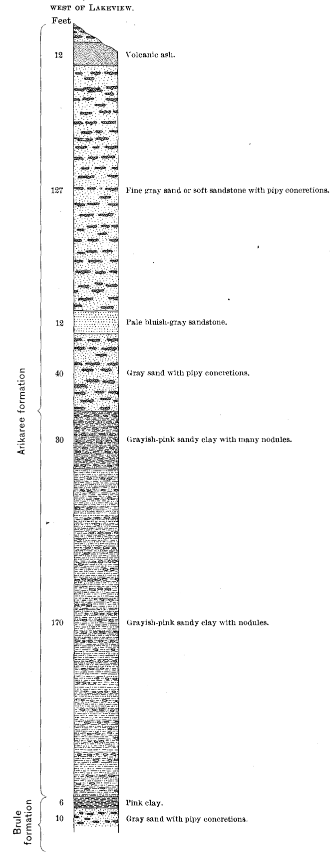
SECTION 2.

Brule formation, 1¾ miles southwest of Doty's Ranch.



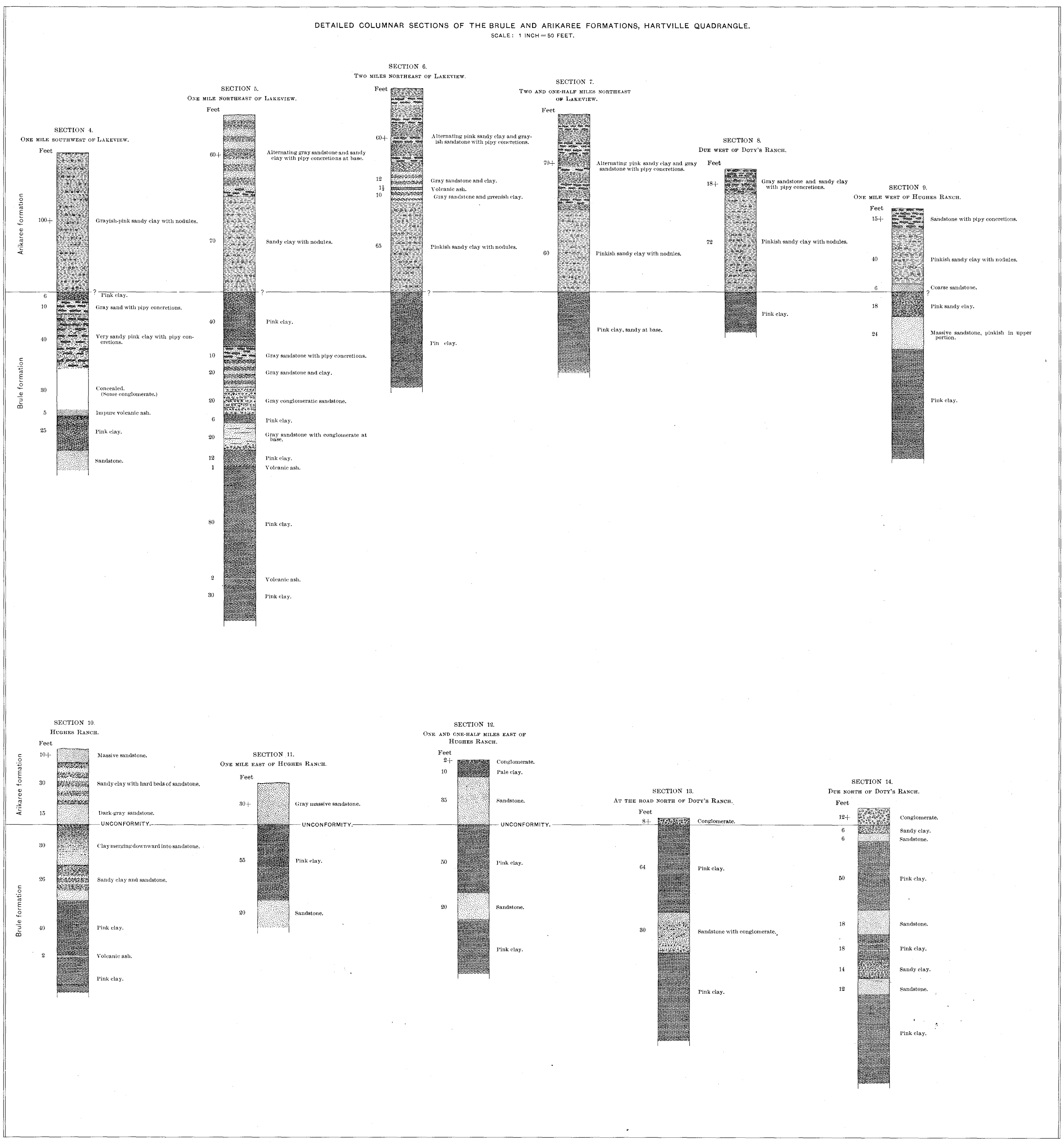
SECTION 3.

Basal portion of Arikaree formation, 1 mile southwest of Lakeview.



W. S. TANGIER SMITH,
N. H. DARTON,
Geologists.

COLUMNAR SECTION SHEET 2



N. H. DARTON,
Geologist.

ILLUSTRATION SHEET

FIG. 1.—BUTTE CAPPED BY A BED OF SANDSTONE IN THE ARIKAREE FORMATION, NORTHEAST OF BOXELDER SPRINGS.

The butte has been determined by the resistant character of the sandstone, and the weathering at its margin has developed columnar structure.

FIG. 2.—OLD GRAVEL-CAPPED RIVER TERRACE OF NORTH PLATTE RIVER, NORTHEAST OF CASSA.

Terrace is on the Arikaree formation. Hartville formation in the background.

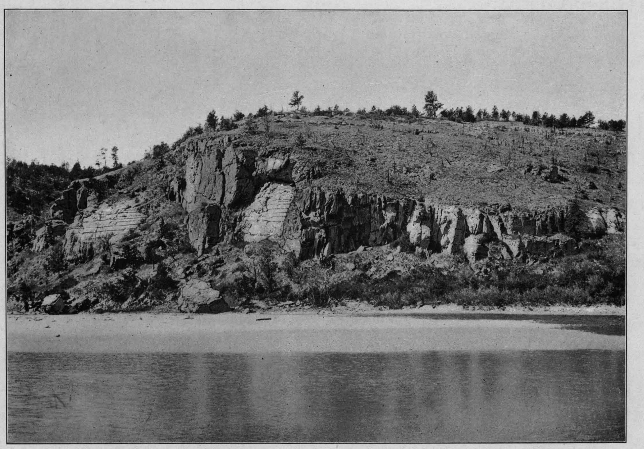


FIG. 3.—CLIFF OF CARBONIFEROUS ROCKS ON THE WEST SIDE OF NORTH PLATTE RIVER, JUST ABOVE FAIRBANK.

Showing the jointed, massive quartzite at the base of the Hartville formation resting unconformably on the bedded limestone of the Guernsey formation.

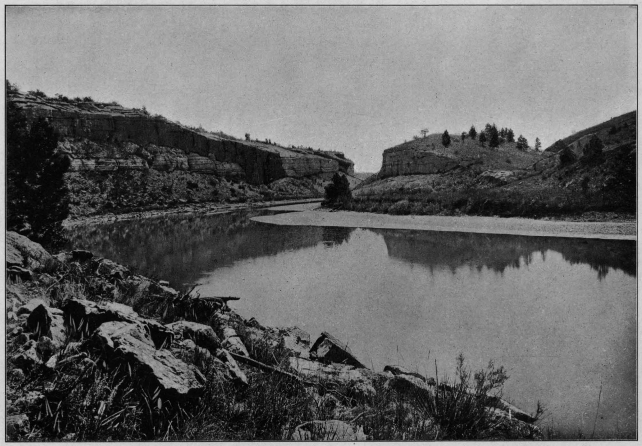


FIG. 4.—CANYON OF NORTH PLATTE RIVER WEST OF FAIRBANK, LOOKING EASTWARD.

Showing the massive quartzite at the base of the Hartville formation resting unconformably on the bedded rocks of the Guernsey formation.

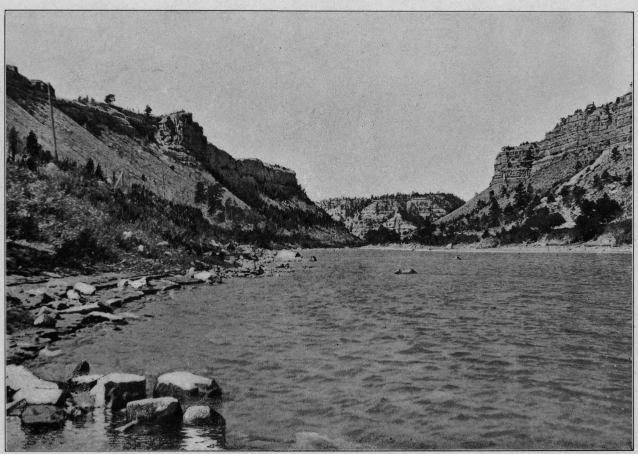


FIG. 5.—CANYON OF NORTH PLATTE RIVER, ONE AND ONE-HALF MILES ABOVE WENDOVER, LOOKING NORTHWESTERLY.

A characteristic view of the canyon, which has been cut in the rocks of the Hartville formation.

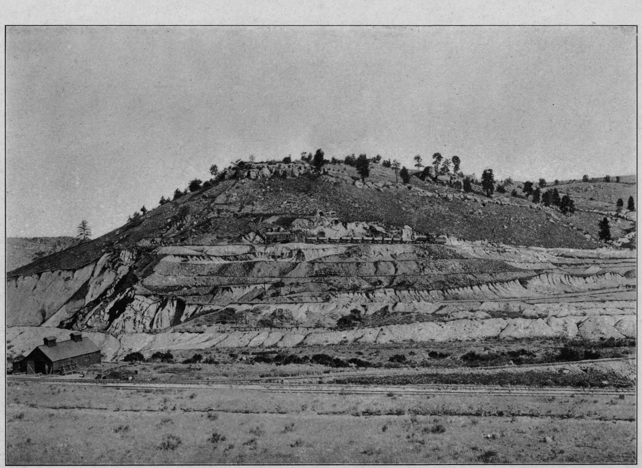


FIG. 6.—GENERAL VIEW OF THE IRON MINE AT SUNRISE.

Deposit of hematite in the Whalen group. Guernsey and Hartville formations form the top of the hill. Photograph taken in the summer of 1901.

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36	Pueblo	Colorado	50
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40	Wartburg	Tennessee	25
41	Sonora	California	25
42	Nueces	Texas	25
43	Bidwell Bar	California	25
44	Tazewell	Virginia-West Virginia	25
45	Boise	Idaho	25
46	Richmond	Kentucky	25
47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Mass.-Conn.	50
51	Big Trees	California	25
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
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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
84	Ditney	Indiana	25
85	Oelrichs	South Dakota-Nebraska	25
86	Ellensburg	Washington	25
87	Camp Clarke	Nebraska	25
88	Scotts Bluff	Nebraska	25
89	Port Orford	Oregon	25
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91	Hartville	Wyoming	25

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‡ These folios are out of stock.

Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.