DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS

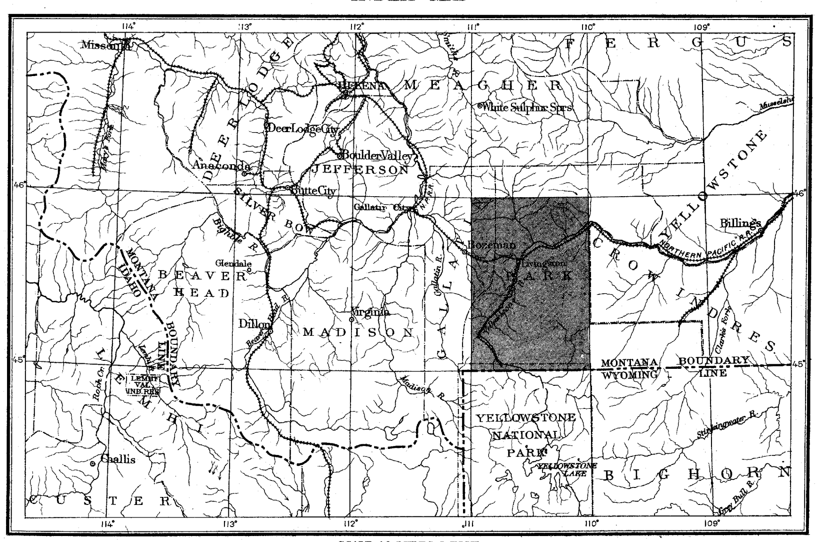
OF THE

UNITED STATES

LIVINGSTON FOLIO

MONTANA

INDEX MAP



SCALE: 40 MILES-1 INCH

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FOLIO 1 | LIBRARY EDITION | LIVINGSTON

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS   S.J. KÜBEL, CHIEF ENGRAVER

1894

EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (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 stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

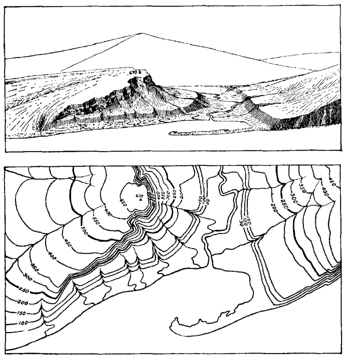


Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. 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 height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur 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 so on with any other contour. In the space between any two contours occur 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 are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal 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 define all prominences. The relations of contour characters 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. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$ the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

Culture.—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding 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 special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as 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 "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$, to about four square miles; and on the scale of $\frac{1}{250,000}$, to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. These areas correspond nearly to 4000, 1000 and 250 square miles.

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. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

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 in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface 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 oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch 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.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. 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 one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

PERIOD.	SYMBOL.	COLOR—PRINTED IN PATTERNS OF PARALLEL LINES.
Neocene (youngest)	N	Yellowish buff.
Eocene	E	Olive-brown.
Cretaceous	K	Olive-green.
Juratrias	J	Gray-blue-green.
Carboniferous	C	Gray-blue.
Devonian	D	Gray-blue-purple.
Silurian	S	Gray-red-purple.
Cambrian	Є	Brown-red.
Algonkian (oldest)	A	Orange-brown.

In any district several periods may be represented, and the representation of each may include one or many formations. 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; and the formations of any one period are distinguished from one another by different patterns. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital letter-symbol of the period. 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.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture.*—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales;* but when rocks of any class are found in thin layers that are due to pressure they are called *slates.* When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists,* a term which applies to both shaly and slaty structures.

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

Metamorphic crystalline formations 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 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 only.

USES OF THE MAPS.

Topography.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

Areal geology.—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend,* which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern 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 colored 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 of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

Economic geology.—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 geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. 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 in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

Structure sections.—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial 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.*

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. 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. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

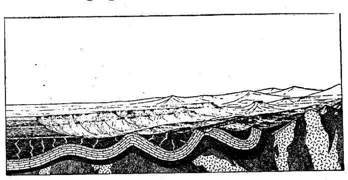


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows 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:

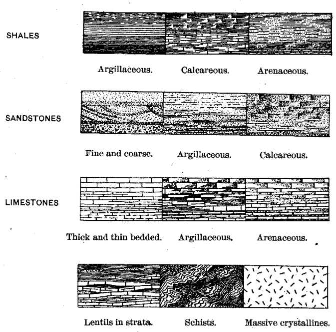


Fig. 3. Symbols used to represent different kinds of rocks.

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder 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 thicknesses can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

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. But these sandstones, shales and limestones were deposited beneath the sea in nearly flat sheets. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable.*

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, 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 or upon their upturned and eroded edges, the relation between the two is *unconformable,* and their surface of contact is an *unconformity.*

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been 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 group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only 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 of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

Columnar sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram. The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

J. W. POWELL,
Director.

LIVINGSTON ATLAS SHEET.

DESCRIPTION.

GEOGRAPHY AND TOPOGRAPHY.

The area of country covered by the Livingston sheet lies between the parallels of latitude of 45° and 46° and the meridians of 110° and 111°, embracing 3,340 square miles. It lies wholly in Montana, the line of parallel 45° forming the boundary between that state and Wyoming. It includes portions of Gallatin and Park counties, and derives its name from Livingston, the most important town within its limits. It is an elevated region, wholly above an altitude of 4,000 feet and mainly above 6,000 feet, the highest peaks being over 11,000 feet above sea level.

Immediately south of this area is situated the Yellowstone National Park, which, with the exception of a narrow belt of country in Montana and a still narrower one in Idaho, lies in the State of Wyoming. The central portion of the National Park is essentially a broad volcanic plateau, with an average elevation of 8,000 feet, surrounded on all sides by mountains with culminating peaks and ridges rising from 2,000 to 4,000 feet above the inclosed tableland. Mountains and plateau, taken together, present an elevated region 75 miles in length. Two of the ranges against which the volcanic rocks of the Park plateau rest, the Gallatin and Snowy, extend northward into Montana.

The principal topographical and geographical features of the Livingston sheet are the Snowy range, Gallatin range, Bridger range, Crazy mountains and Yellowstone valley.

The Yellowstone river is the main drainage channel for this region, receiving all the waters except a few small streams on the west side of the Gallatin and Bridger ranges. It has its source in Yellowstone lake on the Park plateau. Flowing northerly through the Grand canyon of the Yellowstone, and thence westerly along the southern slopes of the Snowy range, it leaves the Park near the boundary of Montana. Thence north to Livingston it flows through a broad valley inclosed by mountains of bold aspect. This valley widens to three miles and is over 30 miles long. Just before reaching Livingston the river traverses a narrow gorge cut through uplifted sedimentary rocks, exposing an excellent section across the Paleozoic strata. Thence, making a sharp curve, it flows easterly across the great plains of the upper Missouri river. The Yellowstone valley sharply divides the Gallatin range on the west from the Snowy range on the east. Beyond the great curve in the river near Livingston the broad valley separates the Snowy range from the long slopes of the Crazy mountains.

The Snowy range occupies a third of the area represented on the map and is encircled by the Yellowstone river. The eastern part of these mountains is characterized by high plateaus and table-topped ridges, which differ greatly in origin as they do in materials. The surface of the plateau of gneiss which is drained by the Boulder river and its tributaries appears to have been planed to the level of an ancient sea. The streams then flowing could cut no lower than their mouths, but the plateau has since been elevated with reference to the sea and is being carved by modern streams. The flat tops of the volcanic ridges to the south of the gneissic plateau are formed by nearly horizontal beds and sheets of lava.

Along the west side of the Yellowstone valley the Gallatin range trends north and south with peaks and crags rising high above the river. The greater part of the range lies west of the meridian of 111° outside the limits of the map. Beyond the Gallatin range, the Bridger range stretches northward for a long distance, and its western spurs also extend across the map limits. The western side of the range rises grandly above the Gallatin valley, but the eastern side falls away more gradually toward the shallow valley of Shields river, which separates it from the Crazy mountains. Only the southern end of the Crazy mountains comes within the limits of the map. They form a somewhat isolated mountain mass standing out prominently by itself and sharply defined by geographical and geological features from the Bridger and Snowy ranges. The highest peaks are rugged and everywhere present a bold ascent from the gently rising plain.

GENERAL GEOLOGY.

The oldest rocks of this region are crystalline schists and gneisses, generally regarded as belonging to the earliest rock formations that make up the crust of the earth, and designated as of Archean age. They present great variations in their mineral and physical features, and their original character has been altered by movement and pressure. Upon these Archean rocks was laid down unconformably a series of sediments made up of sandstones, conglomerates and slates derived from degradation of an Archean land surface. They carry no organic remains. This series of beds is considered to belong to the Algonkian period. On the Livingston sheet they occupy only a small area in the Bridger range, but to the west and north they form a large part of the Belt mountains.

THE CONFORMABLE SERIES.

The Algonkian rocks sank and were deeply buried under a great thickness of Paleozoic and Mesozoic strata. These deposits are conformable from the lowest Cambrian strata to the summit of the Laramie coal measures of the Cretaceous period, and rest unconformably upon the crystalline schists throughout the greater part of the region, except where conglomerates, assumed to be Algonkian, underlie recognized Cambrian beds.

The Paleozoic and Mesozoic rocks consist of limestone, sandstone and shale deposited under varying physical conditions. Much of this material was laid down in shallow seas, other portions in relatively deep waters. Some of the coarser beds bear unmistakable evidence of being inshore deposits, while portions of the finer material were probably deposited farther from land.

GEOLOGICAL RELATIONS OF THE MOUNTAIN RANGES.

Snowy and Bridger ranges.—Late in Cretaceous time the region was once more elevated above the sea, and the horizontal strata of Paleozoic and Mesozoic ages were folded. The plication and folding of strata, as developed in the Snowy and Bridger ranges, took place during this period of continental elevation. These form a part of the system of mountains which stretches across Colorado, Wyoming and Montana, constituting what have been designated the front ranges of the Rocky mountains. Structurally these two ranges are closely related, but they are sharply contrasted in the trend of the uplifted rock masses.

The structure of the Snowy range is that of a broad anticlinal fold whose axis trends northwest by west, accompanied by minor folds and modified more or less by profound faulting. The uplifted axis of this anticline is exposed in the high plateaus and mountains of Archean gneiss and crystalline schist situated in the center of the area that terminates abruptly in the mountains along the Yellowstone valley between Deep and Elbow creeks. On its northern side the gneiss passes beneath Paleozoic strata dipping steeply northward. South of Mount Cowen, at their western end, the Archean rocks are bounded by a profound fault which has a steep hade to the south and dies out to the east where the area of gneissic rock broadens and extends southward; it finally passes beneath slightly inclined Paleozoic strata dipping south.

South of the profound fault already mentioned the gneiss reappears, but it has been dropped several thousand feet. The southern part of it rises high again in the mountains along the Yellowstone valley. Near the fault it passes under Paleozoic beds dipping southward, which form the remnant of one limb of a synclinal fold that has been dislocated by a fault trending southeast by east. This latter fault bounds the gneissic axis on the south and, extending beyond the southern boundary of the map, is lost beneath lavas. The small area of Cretaceous rocks south of this fault represents the other limb of the synclinal fold.

In the northern half of the Livingston sheet the folding of the Paleozoic rocks presents several features of interest. Along the northern flanks of the Snowy range the Paleozoic beds, instead of passing directly beneath the great accumulation of Mesozoic beds at their base, are crumpled in the common (S-shaped fold.) This is frequently faulted, but with differential throw, so that three distinct areas of the Archean schists are brought up entirely surrounded by Paleozoic rocks.

West of the Yellowstone river, as well as east of it, topographic relief expresses geologic structure; the mountain ridges are (anticlinal folds) of the resistant Paleozoic limestones denuded of the soft Mesozoic beds. The intervening synclinal valleys are cut in the soft Cretaceous shales. North of the Gallatin range this structure prevails in Canyon mountain and the low mountains to the west, which show three parallel folds lying en echelon and trending north-northwest. As has been found to be the case elsewhere in the Rocky mountains, these folds, lying en echelon, show a much steeper dip on the west than on the east side—a pushing over of the folds to the west with an abrupt and sometimes overthrown dip of the beds westward.

The Bridger range presents the eastern slope of a long anticlinal uplift which is overthrown at the south end where schists and gneisses rest upon inverted Paleozoic strata. The Paleozoic beds forming the crest dip steeply, with the overlying Mesozoic strata, beneath the sharply folded conglomerates and clays of the Livingston beds. These flatten out in the valley of Shields river and form the broad benchlands about the Crazy mountains.

After the region was uplifted at the close of the Laramie the surface of the country was greatly modified by erosion, valleys and mountains being carved from the newly formed land. Subsequently a vast amount of volcanic and other igneous rocks were erupted, modifying still more the earlier configuration of the country. In a few instances volcanic action was contemporaneous with the folding of sedimentary rocks. The material derived from the degradation of the land rests unconformably on the Laramie coal measures and forms the Livingston beds, in which fragments of many earlier rock masses may be recognized. The earliest outbursts of volcanic breccias furnished a large amount of material for the steadily accumulating Livingston beds, which near their base carry broad masses of both coarse and fine material almost wholly derived from volcanic sources.

Volcanic eruptions that began in late Cretaceous time, as shown by the accumulations in the Livingston beds, attained their greatest activity in the Tertiary age, continuing, with longer or shorter intervals of rest, throughout the Neocene period. In a number of localities large masses of igneous rocks are known to penetrate the upper beds of the Livingston, and in others to overlie the formation. In the Yellowstone valleys the latest eruptions of basalt overlie late Pliocene strata.

Crazy mountains and Gallatin range.—Only the southernmost peaks of the Crazy mountains are included within the limits of the map. The mountains do not form a part of the system constituting the front ranges of the Rocky mountains, but lie to the east of that system. They stand out as an isolated mountain mass and are of later age. The central portions of the mountains consist in part of igneous rocks that have broken through the Livingston beds which lie in a broad synclinal trough. This syncline extends from Shields river on the west to the eastern limits of the map, and south to the Yellowstone river. On the steeply inclined slopes that rise from broad terrace levels, the strata are baked and hardened by the intrusion of innumerable dikes whose sources are to the north. The beds dip at low angles into the mountains from every side, but approaching the center the inward dip becomes less, and about the border of the volcanic masses they dip outward at steep angles as a result of the intrusion of volcanic sheets. Volcanic rocks and the baked and hardened shales and sandstones resist erosion so that the range presents the highest strata of the continuous sedimentary series to be found in the region.

The Bridger and Gallatin ranges are closely connected. East of the meridian of 111°, the latter range is almost wholly made up of volcanic rocks. At the northern end of the range, breccias and lava-flows of andesite and basalt rest against the upturned edges of sedimentary rocks. From about the parallel of 45° 30′ these volcanic rocks extend southward into the Yellowstone Park. They are roughly bedded and lie inclined at about 5° to the east. They are evidently of great thickness, as deeply eroded canyons at the northern end fail to expose any underlying rocks. It is only at the southern end of the range that the sedimentary rocks again appear at the surface, along Yellowstone valley near Cinnabar mountain.

DISTRIBUTION OF VOLCANIC ROCKS.

The most extensive areas of volcanic rocks are found in the southern half of this region. Here they consist of tuffs and breccias with lava flows. Volcanic centers of eruption may be recognized in at least five localities by the arrangement of dikes that radiate from various places within or near ancient conduits. This is the case at Electric peak, Emigrant gulch, Haystack peak, the head of Deer creek and the Crazy mountains, and the country surrounding each of these localities. Bodies of diorite and gabbro occupy what were once volcanic conduits at Electric peak, Haystack peak and in the Crazy mountains. A great body of porphyrite fills the conduit at Emigrant gulch. These have hardened and altered the character of the rocks surrounding them. Other large bodies of porphyrite occur in the southern portion of the region. Their form is irregular, as in some instances they have forced their way between sedimentary beds, and in others through volcanic breccias. Where they were injected between beds of limestone or sandstone they form thin sheets that may be traced for long distances, usually following layers of shale. A prominent example is Sheep cliff, 12 miles east of Livingston.

After the country was eroded almost to its present form there were eruptions of rhyolitic and basaltic lavas that flowed over the low ground and down valleys. Remnants of basalt flows occur in the Yellowstone valley at various places from Gardiner to Fridley.

TERTIARY LAKE BASINS.

In the folding of rock masses that accompanied or soon followed the continental elevation after the deposition of the Laramie coal measures, depressed areas were formed between sharply defined mountain ranges. In some instances these basins became fresh water lakes that gradually filled up during Tertiary time with material derived from both sedimentary and volcanic rocks, washed down from the surrounding mountains. These areas have been designated as the Tertiary lake basins of the Rocky mountains. On the Livingston sheet they occur only in limited areas, being found along the eastern edge of the Gallatin valley and again in the broad valley of the upper Yellowstone. In the latter locality the loose marls and conglomerates that make up the deposits have for the most part been carried away by erosion, only small areas being protected here and there by overlying basalts, the latest volcanic lava-flows of the region.

GLACIATION.

The glaciers that covered the greater part of the mountains in Pleistocene time and forced their way down into the lowlands, though of large size, were local in character. In the Snowy range the rocks were scored and polished by ice sheets and the canyons deepened and broadened. A large confluent glacier filled the gorges of the Boulder, leaving a great accumulation of morainal debris upon the hill slopes. In the valley of the Yellowstone the magnitude of the glacier which flowed northward from the Yellowstone Park is everywhere apparent. Local glaciers from the high peaks eastward have left imposing morainal embankments at the mouths of tributary valleys and in the Bridger range and in the Crazy mountains local glaciers existed whose moraines of angular debris are prominent among the lesser features of the foot-hill slopes.

Since the melting of the glaciers the rivers have deposited fine gravel, sand and alluvium in beds that now form the valley terraces and fertile flood plains.

DESCRIPTIONS OF THE SEDIMENTARY ROCKS.

Sedimentary rocks cover nearly one-half of the 3,340 square miles of the Livingston sheet, and they embrace a total thickness of 20,000 feet in which all the grand divisions of geologic time since the Archean are represented. The most striking feature of the various strata deposited within this region is the great development of Cretaceous, or, to be more exact, of the latest Cretaceous strata, of which there is a thickness of 12,000 feet above the Laramie coal measures, while the formations of the Paleozoic age attain a total thickness of but 3,500 feet.

The Paleozoic strata, which are in general the mountain-forming rocks of the series, occur upturned at steep angles against the crystalline schists or in sharp anticlines. The lowest bed is a quartzite long recognized in the Rocky mountain region and generally regarded as the base of the Paleozoic system, overlain by shales and limestones of undoubted Cambrian age. The Silurian period is represented by a few feet of limestone whose fossils furnish a doubtful criterion for its determination, while the Devonian period is clearly defined by its sediments, though they average but 450 feet in thickness, as well as by the evidence of fauna. The Carboniferous is more conspicuously represented than the other periods. Its massive beds of limestone, averaging 2,000 feet in thickness, form the crest of the Bridger range and the summits of many of the peaks of the Snowys.

The Trias is recognized in the red sandstones of Cinnabar mountain, but thins out northward and can not be discriminated in the northern part of the sheet. The Jurassic also varies through a wide range of character within this region. The combined thickness of deposits of the Juratrias period is 500 feet.

The rocks of the Cretaceous period compose more than half the entire thickness of sedimentary strata. At the base of the series is a conglomerate known as the Dakota which is a readily recognizable horizon throughout the region. The marine Cretaceous, as often elsewhere, is not typically developed so near the mountains, the beds alternating rapidly and containing much sandstone.

The conformable series of strata ends with the Laramie. This formation is about 1,000 feet thick and has proved coal-bearing throughout the region. The Laramie is succeeded by volcanic tuffs and sandstones of the Livingston beds, recording ash showers deposited in shallow waters. These are succeeded by massive conglomerates whose pebbles were produced by erosion of a land surface at no great distance from the place of their deposit. The highest beds assigned to the Cretaceous have been preserved in the Crazy mountains by local hardening and the intrusion of volcanic rocks.

Neocene rocks are represented by strata deposited in two intermontane lakes which occupied the upper Yellowstone and the Gallatin valleys respectively. Pleistocene deposits, though in many parts of the area a prominent feature of the present scenery, are not generally indicated. Chemical deposits formed by hot springs occur at four localities, but are important only near Gardiner.

STRATA OF THE ALGONKIAN PERIOD.

Belt beds.—The sandstones, conglomerates, slates and arenaceous limestones called the Belt beds, which are provisionally assigned to the Algonkian, occur only upon the western flanks of the Bridger range within the limits of this sheet. At this locality the beds are conglomerates and are generally reddish and quite massive and dense. They rest unconformably upon Archean schists and are overlain by the Flathead quartzite. The beds are distinguishable by their rough outcrops, generally densely wooded with pines and forming a chain of detached knobs upon the western spurs of the range. A thickness of about 2,500 feet has been observed at this locality, but this is very much exceeded farther westward and in the mountains of the Belt range.

STRATA OF THE CAMBRIAN PERIOD.

The Cambrian rocks constitute readily recognizable formations in the region of the map. They include a considerable variety of quartzites, shales and limestones whose characters are persistent over large areas, rendering the recognition of horizons comparatively easy. Fossils are abundant in the upper of the two divisions into which the series has been divided, and they show an undoubted Cambrian fauna. In the Bridger range near Flathead pass the rocks of this period rest in apparent conformity upon the Belt beds, assigned to the Algonkian, but elsewhere they lie directly upon the crystalline schists and gneisses.

The Flathead quartzite and shales form the base of the Paleozoic series recognized in this region. The lowest bed, a quartzite, is a compact rock varying from white to yellow or red, occasionally mottled, and often grading into conglomerates at the base. Resting upon this bed, is the heavy shale belt 200 feet thick, topographically distinguishable from a distance by the sag or ravine that often marks this horizon. The shales are green or purple, finely laminated and micaceous. The overlying limestones are very thinly bedded, somewhat impure, and carry fragmentary fossils indicating the middle Cambrian. The shales at the top are black and friable and generally barren of fossils. Good exposures occur in the Bridger range, on Deep creek and in the canyons of the Boulder river.

The Gallatin limestone forms the upper portion of the Cambrian series, with a thickness of 500 feet. It consists of massive and of thinly bedded limestones separated by beds of purple and green shale. The uppermost beds are pebbly limestones containing fossils which may be of Silurian age; the thinly bedded limestone conglomerates alternate with crumbly earthy shales. These conglomerates rest directly upon a persistent stratum of shale that overlies the most prominent bed of the Cambrian series; this bed is a massive limestone, characteristically mottled with buff and black spots, which forms a well defined escarpment 240 feet high. At its base this mottled limestone grades into thinly bedded limestones and conglomerates, speckled with green glauconite grains and carrying an abundance of fossil remains of upper Cambrian types.

STRATA OF THE DEVONIAN PERIOD.

The rocks of the Devonian, having a total thickness of only 450 feet in this region, are inconspicuous. They embrace two divisions, an upper thinly bedded group of shaly strata, and a lower massive limestone series, sandy at the top.

The Jefferson limestone includes at the top arenaceous beds 75 feet thick, the rocks being drab and possessing a fetid odor. Next beneath is a massive bed of limestone 125 feet thick that forms a persistent and very prominent bluff wherever the rocks are well exposed. This limestone weathers with a peculiarly rough surface and has yielded few fossils.

The Three Forks shale consists of very thinly bedded impure limestones alternating with thin beds of shale, the whole being 250 feet thick. At the top the beds are often red or purple; the lower strata are earthy shales in beds a few feet thick, alternating with limestone layers of equal thickness. The fossils contain characteristic Devonian species.

STRATA OF THE CARBONIFEROUS PERIOD.

The rocks of the Carboniferous consist of two formations, lithologically distinct, the uppermost being essentially siliceous. The main body of these rocks is of massively bedded limestones that weather into rough and rugged masses forming the peaks of the Bridger range and the crests of the chain of summits on the north end of the Snowy range. The great resistance offered by these rocks to erosion brings them into relief, in strong contrast to the overlying Mesozoic formations.

The Madison limestone consists of about 1,800 feet of limestone separable into two divisions. The upper 600 feet of beds consist of very massive limestones which rarely show bedding-planes. They are light gray, seldom contain fossils, and weather into most rugged and precipitous masses. The lower limestones are more thinly bedded and darker and are rich in fossil remains. At the base there is a rather abrupt change from the sandy beds of the Devonian. Good exposures occur in the canyon south of Livingston, the picturesque gorge known as Rocky canyon, and along the forks of the Boulder river.

The Quadrant quartzite consists of white or pinkish, compact beds with intercalated drab or cream-colored limestones. These beds average 300 feet in thickness, and are the uppermost of the mountain-forming rocks. In the lower strata the beds grade into impure arenaceous limestones frequently characterized by a large amount of earthy magnesian rock weathering into red clay. In the southern part of the region the series is capped by an impure, dark brownish drab quartzite, carrying concretions of chert.

STRATA OF THE JURATRIAS PERIOD.

The Ellis limestone.—These beds consist of an overlying sandy limestone underlain by the Myacites beds, which are impure fossiliferous limestones with sandstones at the base. The aggregate thickness is about 400 feet. The uppermost bed is a very persistent horizon that is sometimes a granular calcareous sandstone passing into a compact, coarsely crystalline white limestone, and is always characterized by an abundance of shell fragments. The underlying Myacites limestone is a grouping of soft, earthy calcareous beds, dark gray, and generally weathering into narrow depressions between the Dakota ridges and the steep mountain slopes. These limestones contain an abundance of fossils, *Myacites subcompressa* being especially prominent.

At Cinnabar mountain the Myacites beds rest upon a massive, cross-bedded, ripple-marked sandstone, underlain in turn by a bright red sandstone which may be the equivalent of the Red-bed sandstones of more southern localities.

STRATA OF THE CRETACEOUS PERIOD.

Rocks of the Cretaceous cover the northern third of this sheet, and by far the larger part of the area occupied by sedimentary beds. The highest rocks are those forming the Crazy mountains where the strata have been preserved by induration. In general Cretaceous beds form the foothills and the lower open country. They embrace 16,000 feet of strata, or the larger part of the sedimentary section, and are divided into five groups, of which the Dakota is the lowest member and the Livingston the highest.

The Dakota sandstone.—This formation consists of three members: sandstones with conglomerates near the base, reddish clays above, and a thin bed of fossiliferous limestone and massive quartzite on top. The formation is conspicuous topographically, as the siliceous beds form the crest of long monoclinal ridges parallel to the base of the mountains. The quartzite capping is a very dense massive bed 60 feet thick. The shale beds are often red or purple and they vary rapidly in character. They are generally capped by a drab limestone carrying fresh water fossils. The conglomerate is the characteristic feature of the formation and is a readily recognizable horizon; it consists of well rounded, vari-colored, firmly cemented, siliceous pebbles, which break with the matrix. The conglomerate forms but part of the basal sandstone, its position in the bed varying at different exposures.

The Colorado.—This group embraces the two subdivisions, the Benton shales and the Niobrara limestone, aggregating 1,800 feet thick in this region. The line of separation is not readily recognizable, lithologically, although the general characters of the two horizons are quite unlike.

The Benton shales consist of thinly laminated black shales generally covered on the outcrop by soil and vegetation. The exposures at Cinnabar mountain and the northern flanks of the Snowy range show shales differing but little from those characteristic of the formation in general, while the strata along the northern flanks of the Gallatin mountains are much more sandy. Marine fossils and indistinct vegetable remains characterize the beds.

The Niobrara limestone contains much clay and and frequently grades into shales with interbedded clayey sandstones. The beds weather easily, but do not crumble into the black earths characteristic of the underlying Benton. Good exposures occur at Cinnabar mountain, near Cokedale and in the bluffs along Boulder river.

The Montana.—This group of the Cretaceous embraces the two subdivisions known as the Fox Hill sandstones and the Pierre shales, attaining a total thickness of 1,800 feet. There is a transition in character of sediment and in forms of life between the two formations.

The Pierre shales are leaden gray and often sandy, and they resemble the overlying Fox Hills, from which they sometimes differ little save in being softer and darker. The beds carry occasional lenticular bodies of impure limestone and sandstone and contain alkaline salts and gypsum.

The Fox hills beds are quite earthy and impure in this region and the characteristic sandstone capping is not generally recognizable. The rocks are usually thinly bedded, and frequently weather in long lines of slabs resembling tombstones. They are gray and not readily distinguished from the underlying shales.

The Laramie.—This formation consists of light colored, cross-bedded sandstones with interbedded clays and coal seams, and is economically the most important of the sedimentary formations. The upper beds are characterized by abundant concretions resembling cannon balls. The strata are readily distinguished from the leaden gray Montana shales beneath and the dark brown beds of the Livingston above. Good exposures occur along Boulder river and in the disturbed region west of Livingston, where the coals are mined. In the Bridger range the rocks are generally concealed by glacial material and the later accumulation of mountain debris, but they are well exposed in Bridger canyon. In the southern part of the sheet the Laramie is seen in fine exposures in the cliffs of the long, northeast spur of Electric peak, the coals being mined at Horr. Plant remains have been found in the shales overlying the coal beds and fresh water shells in the sandstones. The average thickness is about 1,000 feet, estimating from the top shales of the Montana to the base of the Livingston grits.

The Livingston.—This formation consists of a great thickness of conglomerates, sandstones and clays, with local intercalations of volcanic agglomerates and breccia near the base. The rocks rest upon the white sandstones of the Laramie coal measures, from which the lower beds of this series are readily distinguishable by their sombre color. By far the larger part of the area occupied by sedimentary beds is covered by these rocks, in which are provisionally included those strata which form the Crazy mountains and may prove to be of Fort Union age. These upper strata, 5,000 feet in thickness, consist of light earth-colored or white sandstones, leaden clays and shales, with small lenticular bodies of impure limestone; they contain fresh-water shells and plant remains.

The lower portion of the series of beds belonging to the Livingston horizon differs materially from those just described. In a thickness of 7,000 feet there is a shaly upper portion resting upon grits and sandstones that become coarse conglomerates in the high hills east of the Bridger range, and a basal division of dark, poorly assorted grits and sandstones characteristically composed of volcanic material and containing abundant fossil leaves. An intercalation of true volcanic agglomerate occurs in this part of the series, in the region drained by the Boulder river. The conglomerates of the Livingston are best exposed in the foot slopes of the Bridger range and the high hills east of that range. The pebbles are well rounded and consist chiefly of a variety of volcanic rocks, but include gneissic and quartzitic pebbles together with others of Paleozoic limestone and Cretaceous rocks. The lower beds are well exposed above the coal at Cokedale, Timberline and the valley of Billman creek. The long railroad tunnel across the Yellowstone-Missouri divide is cut in the shales of this series.

STRATA OF THE NEOCENE PERIOD.

Bozeman lake-beds.—The conglomerates, sandstones and clays deposited in the waters of a lake that once occupied the Gallatin valley, receive their name from the town of Bozeman. The rocks are loosely cemented and consist of a variety of materials derived from the adjacent mountain slopes, with marls and layers of volcanic dust. The thickness exposed within this area is about 1,200 feet, but it is greatly exceeded in other parts of the Gallatin valley. The beds are slightly tilted, dipping at angles of 2° to 3° westward, and rest unconformably upon Archean schists and all sedimentary strata, including the Livingston. Fine exposures occur in the bluffs along the north bank of the East Gallatin river, near Fort Ellis.

A smaller area of lake-beds assigned to this age occurs near Fridley, in the upper Yellowstone valley. The rocks consist of light cream-colored marls, becoming conglomerates near Fridley. Upon these streams gravels were deposited and these were subsequently covered by a basaltic lava flow. These beds were formed in an independent lake occupying this part of the Yellowstone valley.

SUPERFICIAL DEPOSITS OF THE PLEISTOCENE PERIOD.

Glacial drift.—Gravel, sand and boulders of a great variety of crystalline, igneous and sedimentary rocks cover the surface of a large part of the valley from Chicory southward. Occurring generally in a confused assemblage of hillocks, five to twenty feet high, they form the terminal moraine of the glacier that once occupied this part of the valley.

Assorted drift.—Sands and gravels assorted by water form broad terrace levels in the mountain valley of the Yellowstone near Chicory and along Mill creek. They consist of the deposits of glacial streams and form the old overwash plain of the glacier that once filled the valley. The material varies from fine sand to coarse gravel, is more or less water-worn, and is coarsest near the moraines of glacial drift.

Alluvium.—The fluviatile deposits classed as alluvium consist of the clays forming the river-bottom lands, together with the sands and gravels that form the river benches in the mountain valley of the Yellowstone. In general the alluvial deposits have not been indicated upon the map; they are usually found in all the wider valleys.

Travertine, a calcareous tufa or limestone formed by the waters of hot springs now extinct, covers part of the basalt bench east of the river near Gardiner, and caps a butte opposite the mouth of Bear gulch. The rock is generally compact, white or light yellow in color, and retains the peculiar characters of a spring deposit. It is from 10 to 30 feet thick. A few small hot springs at the mouth of Bear gulch are now forming deposits of this rock, and others opposite Cinnabar mountain were formerly calcareous and deposited a small amount of travertine about their outlets.

DESCRIPTIONS OF THE IGNEOUS ROCKS.

A large part of this area is covered with igneous rocks. They also enter into the composition of one of the conglomerate formations that make up the Livingston strata. They consist of sub-aerial breccias or agglomerates with tuffs and lava flows, and of intrusive bodies such as dikes, sheets, laccolites and stocks or necks. At the southern end of the Gallatin range these breccias rest directly upon crystalline schist. Similar breccia and lava flows extend across the southern portion of the region flanking the area of gneisses and schists, continuing southward into the Yellowstone Park. Another locality of volcanic agglomerates or breccias is on the eastern border of the area between the parallels of 45° 30′ and 45° 45′. These rest unconformably upon Montana, Laramie and Livingston strata, and extend some distance east of the area of the map. With these accumulations of volcanic material are associated bodies of intruded rocks, some large and irregularly defined, others in thin sheets or narrow dikes. The large bodies occur scattered through the region south of the gneissic area and are connected with dikes and sheets. They are associated with the breccia north of this area. In the Crazy mountains they occur without surface lavas of any kind.

EXTRUSIVE ROCKS.

The andesitic breccias or agglomerates present a variety of characters, the most typical being that of angular fragments of all sizes cemented together by finer material of the same composition. The fragments differ often in color and appearance, but are usually closely allied in composition. These masses of breccia are in places roughly bedded and alternate with layers of lava that have poured out over the surface during the accumulation of the breccia. In places there is a distinct bedding in the breccia, especially where tuff or volcanic dust is abundant. This is the result of successive showers of dust and stones during volcanic eruptions, and is more noticeable at some distance from the actual source. It is also occasioned in certain localities by the action of waters in streams or lakes, which have rounded the rock fragments and assorted the material to some extent.

The breccias are usually light and in some localities brightly colored, as on the Boulder river and at the Point of Rocks, four miles south of Dailey's on the Yellowstone river, but they are occasionally dark and sombre, appearing at a distance chocolate brown, as in the Gallatin range and in the mountains about the valley of Hellroaring creek. The light colors are in some cases due to decomposition, but they may be the natural and unaltered condition of the rocks.

Acid andesitic breccia is generally light colored, though not always, and consists of hornblende-mica-andesite for the most part. It is usually variegated and is accompanied by very light colored tuffs. In this region it underlies basic breccia, and is therefore, older, as may be seen at the base of Sepulchre mountain, south of Cinnabar and about the head of Boulder river.

Basic andesitic breccia is generally dark colored, and consits of pyroxene-andesite, hornblende-pyroxene-andesite, or basaltic andesite. It occurs in much greater quantity than the acid breccia and constitutes the bulk of all the breccia in this region.

Where both kinds of breccia occur in conjunction, a distinction between them is sometimes sharply marked, but often they merge into one another gradually with no line of demarcation. The upper portion of the basic breccia becomes more and more basaltic and is accompanied by flows of true basalt.

Trachytic rhyolite, in the form of surface lava flows, is intimately associated with the basic breccia and occurs interbedded with it in a few localities—as on Buffalo plateau and Sunset peak. This rock resembles the rhyolite of the Yellowstone Park in general appearance, being both lithoidal and glassy, with marked flow structure, and carrying phenocrysts or porphyritic crystals of sanidine and plagioclase, but none of quartz. It also carries a little biotite, not found in the rhyolites of the region. The lithoidal varieties are light red, and the glassy ones almost black, but they are more like pitchstone than obsidian. These lava flows are not of great thickness, and usually include small fragments of andesite. Their chemical composition places them between rhyolite and trachyte, while in physical aspects they resemble rhyolite.

Rhyolite appears to a very limited extent on the southwest edge of the region, where it is evidently the margin of the great rhyolitic flows of the Yellowstone Park. It is light colored and lithoidal, with phenocrysts of quartz, sanidine and plagioclase. Isolated patches of it occur west of Bear gulch in the extreme corner of the map. It overlies all other volcanic rocks in this region except the most recent basalts.

Basalt in sheets that have been lava flows occurs both in association with basic breccia and as independent bodies of more recent date. The latter are specially indicated on the map; the former are not distinguished from breccia. The later basalt is dark colored and dense, with variable amounts of porphyritic crystals of feldspar, augite and olivine. It is often columnar. It forms prominent ledges in certain localities along the valley of the Yellowstone, especially west of Fridley, in the bluff opposite Dailey's, and that opposite Cinnabar and Gardiner. These are the latest volcanic lavas in the region.

INTRUSIVE ROCKS.

The intrusive igneous rocks are intermediate in age between the andesitic breccias and the rhyolite and latest basalt.

The *gabbro* and *diorite* occur as stocks, or bodies occupying channels through which extrusive lavas have been erupted. The most prominent instance is at Haystack peak. Here the gabbro is medium grained and consists of plagioclase feldspar, augite, hypersthene and biotite as the most essential minerals, the amount of the dark colored minerals being equal to that of the light colored ones. The gabbro grades into a lighter colored crystalline rock, which is diorite, and consists of plagioclase, hornblende, augite and biotite as the essential minerals, the lighter colored minerals predominating. This rock resembles certain fine grained granites in general appearance, but has a different mineral composition.

A similar occurence of diorite is at Electric peak. Here the rock forming the stock varies considerably in grain as well as in composition.

Theralite occurs only in one locality within the area of the map, at the southwest base of the Crazy mountains in a butte north of Pine creek. It forms a massive sheet, 150 feet thick, intruded between sandstone strata. The rock is dark, almost black, and is dense and aphanitic, with abundant phenocrysts of augite and biotite; the feldspathic constituents, plagioclase and nepheline, are confined to the groundmass.

The basic porphyrites and andesites include the larger bodies of intrusive rocks that are basic in composition. They vary from crystalline masses, such as the diorite-porphyrite of Sheep cliff, to rocks but slightly crystalline that would properly be classed as basic andesites. Some of these basic andesites form intruded sheets in the neighborhood of the Crazy mountains and several varieties have been included in one group on the map. On account of the small map-scale the very narrow bodies of intrusive igneous rock, of whatever nature, are indicated by one color. This includes all dikes and thin sheets. They are specially numerous in the Crazy mountains, in the neighborhood of Haystack peak and at Electric peak.

Acid porphyrites, andesites and dacites are grouped together in the legend, and embrace all large bodies of intrusive acid rocks. They range in composition from dacite to hornblende-mica-andesite and include some hornblende-andesites. They exhibit a small range of crystallization from that characteristic of andesite to that of porphyrite. In general they are light colored, aphanitic rocks, with variable amounts of phenocrysts. Some are full of crystals of plagioclase, hornblende and biotite, with or without quartz; others have these minerals with the exception of hornblende; and a small number have very few phenocrysts. The large bodies of these rocks vary in composition in different parts of the same mass, so that no attempt has been made to distinguish their differences on this small scale map. The principal localities for these rocks are: the head of Emigrant gulch, Mill creek, Sunset peak, Slough creek, Electric peak and Sepulchre mountain.

THE CRYSTALLINE SCHISTS.

Granite, gneiss and crystalline schists constitute a part of the southern half of the region. They form the high mountains and plateau drained by Boulder river, and the mountains on the north side of the Yellowstone river from Yankee Jim canyon to the boundary of the Yellowstone Park.

Mica-schists and phillites predominate in the southwestern portion, especially in Sheep mountain and in the vicinity of Bear and Emigrant gulches. With them are associated gneiss and granite, which predominate to the east and form the main body of Boulder plateau. Veins and dikes of crystalline rocks, many of which are distinctly eruptive or of igneous origin, traverse the gneiss, granite and schists. Much of the granite is eruptive and carries angular blocks of other rocks. Gabbro, diorite and diabase also occur and exhibit the effects of metamorphism by pressure.

ECONOMIC GEOLOGY.

GOLD.

Gold-bearing gravels.—The gravels derived from the wearing away of the auriferous rocks of the Snowy range have been worked at Emigrant gulch and at Bear and Crevice gulches. At Emigrant gulch the gravels were brought down to the main valley and deposited by the waters of Emigrant creek. They have yielded large amounts in the past, but have been generally worked out. The gravels of Bear and Crevice gulches have been derived from the quartz veins in the crystalline schists and gneisses; in Bear gulch they have been covered by a basaltic lava flow and are firmly cemented. The Crevice gulch gravels are worked on a small scale; the Bear gulch mines were worked by the hydraulic process for a number of years. Placer ground is also located on the forks of Slough creek and the flanks of Haystack mountain.

Gold veins.—Three mining districts are embraced within the limits of the map: the Emigrant, Crevice and Boulder mines. Outlying prospects of the New World district also occur within this area.

The Emigrant gulch mines are situated on the flanks of Mineral mountain and occur in an igneous rock (porphyrite); a fair grade of ore has been taken from a number of openings.

The Boulder mines are located on the flanks of Haystack peak, at the headwaters of the Boulder river. The ores carry free gold, sulphurets and galena, and occur wholly in the gabbro and diorite.

The Crevice mountain mines are quartz veins in gneiss and schist. One mine is being worked, a number of veins are located and exploring work is being done.

COPPER DEPOSITS.

Copper ores have been found in the region about the head of the Boulder river and in the mountains at the head of Slough creek.

CLAYS.

The chief source of brick clays has thus far been the alluvium of the valley bottoms about Livingston, which burns to a very fair quality of brick. The clays of the Bozeman lake beds have been very successfully used for brick-making. Other clay deposits of value occur in the Cretaceous rocks, but they are not yet utilized.

LIMESTONE.

The limestones of the Carboniferous afford a satisfactory quality of lime and they are quarried and burnt at two localities, Bridger canyon and the canyon of the Yellowstone south of Livingston. The limestones of the Cambrian yield a magnesian lime. The travertine near Gardiner is a very pure carbonate of lime and has been used for lime-making.

BUILDING STONE.

The sandstones of the Laramie coal measures are quarried for building-stone in the vicinity of Livingston and in Bridger canyon. They are easily quarried, occurring in beds 3 to 5 feet thick with interbedded shales, and when fresh are readily cut and dressed. They are largely used for foundations and for ornamental work in the newer buildings of Bozeman and Livingston. The grits of the Livingston beds are also quarried for building purposes. They afford a considerable range of color, and are worked near Livingston and on Boulder river for the town of Big Timber.

COAL.

Two important coal fields are embraced within the limits of this sheet—the Cinnabar field in the south, and the region north of the mountains west of Livingston to which the name of the Bozeman field has been applied. At both these fields the coals occur in Laramie strata. The fuels vary from rather light, dry coals with a high percentage of volatile matter and water, to fairly dense coking coals, like those of Horr and Cokedale, yielding a large output of coke. The thickness of the Laramie strata or coal measure sandstones, estimating from the top of the sandstones to the leaden gray Montana shales at their base, varies in different parts of the region, but is estimated to average 1,000 feet. The sandstones are light colored and cross-bedded, and the individual strata vary rapidly in thickness and character. The lowest seam occurs in both fields at 3,600 feet above the Juratrias beds. The number of coal seams varies greatly at different localities, there being at some places as many as twenty, of which several are each more than 5 feet in thickness. In general, however, only three seams have proved to be of workable thickness and extent. Their aggregate thickness varies from 12 to 18 feet. The coals vary considerably in character in different seams, and even in the same seam, and as the beds occasionally thin out in a short distance or are cut out by sandstones, the expense of mining may be considerable.

The Cinnabar field.—This comprises the area of coal-bearing strata in the vicinity of Cinnabar mountain in the southern part of the map. It embraces the block of Laramie strata capping the long, northeast spur of Electric peak that terminates in Cinnabar mountain, together with the narrow belt of coal-bearing rocks east of the river opposite Gardiner, and the area between the Gardiner and Yellowstone rivers. The coal has been opened at a number of localities, but the only productive workings are the Bowers and the Horr mines. The Horr workings yielded an annual output of about 23,000 tons in 1889. Three seams are worked, their total thickness being 13 feet. The coal is a bright bituminous fuel yielding a fine coke. The block coal meets with a ready sale and the screenings are coked in ovens near the mine.

On the east bank of the river, at the Bowers mine, the coal measures form a narrow block, faulted against the gneiss at the mouth of Trail creek and covered southward by a basaltic lava cap. The seams dip into the mountain at an angle of 40° to 60°, the bed now worked showing 3 feet of clean brilliant coal.

The Bozeman coal field.—This embraces a part of the great belt of coal-bearing, Laramie strata that follows the front of the Rocky mountain system throughout the state. Although the Laramie rocks extend eastward from Livingston, but one opening is worked, all the other mines of the field being west of that town. In this part of the field the coal measures upturned at angles of 40° to 90°, being folded about the flanks of the three anticlinal ridges of Canyon mountain, Timberline and Rock canyon.

At Cokedale the coal measure sandstones are about 900 feet thick, light colored, with the more massive beds forming prominent outcrops of yellow sandrock characterized in certain zones by darker concretions a foot or two in diameter, resembling cannon balls. In general the field has three workable seams, but the fuels vary more than those of the Cinnabar field. At Cokedale the highest of the three seams is worked. Average sections show from 4 to 7 feet of clean coking coal, in three to four benches with sandstone partings of half an inch to six inches in thickness. These partings are variable in thickness, but quite persistent throughout the seam. The two lower beds of coal show from 5 to 7 feet of firm clean coal separated by similar partings. The output at Cokedale was 49,400 tons in 1889. West of Cokedale the coal measures are nearly vertical and the outcrop is S-shaped as the strata curve around the end of the Canyon mountain anticline. There are no productive workings westward until the Yellowstone-Missouri divide is crossed, beyond which the Timberline mines are located. The strata here dip at 45° north into the hill. Five seams have been worked at this place, but the output is now almost wholly from two. The upper of these two seams is 4 feet thick, separated into three benches by partings. The coal is hard, little broken in the seams, and bears handling well. The lower of the two seams worked is 6 to 8 feet thick and rests upon a poorly defined floor of bone and shale. The coal is much crushed, very soft, crumbling in the fingers, quite bituminous, and can be lighted with a match. It is used for blacksmithing at the mines. The output from this seam is mixed with the harder coal of the seam above for the market. The output was 44,000 tons in 1889.

The same seams are worked at the Mountain-Side and Chestnut mines, though the coals change somewhat in character.

A small synclinal basin of the Laramie coal-measures occupies the valley of Trail creek a few miles south of Timberline. Two seams have been worked.

West of Chestnut the coal-bearing strata curve about the anticline of Rocky canyon, reappearing in Bridger canyon where one of the seams has been worked. Although the coal strata extend northward along the east front of the Bridger range, no openings have been made there.

JOSEPH P. IDDINGS,
Geologist.

WALTER H. WEED,
Geologist.

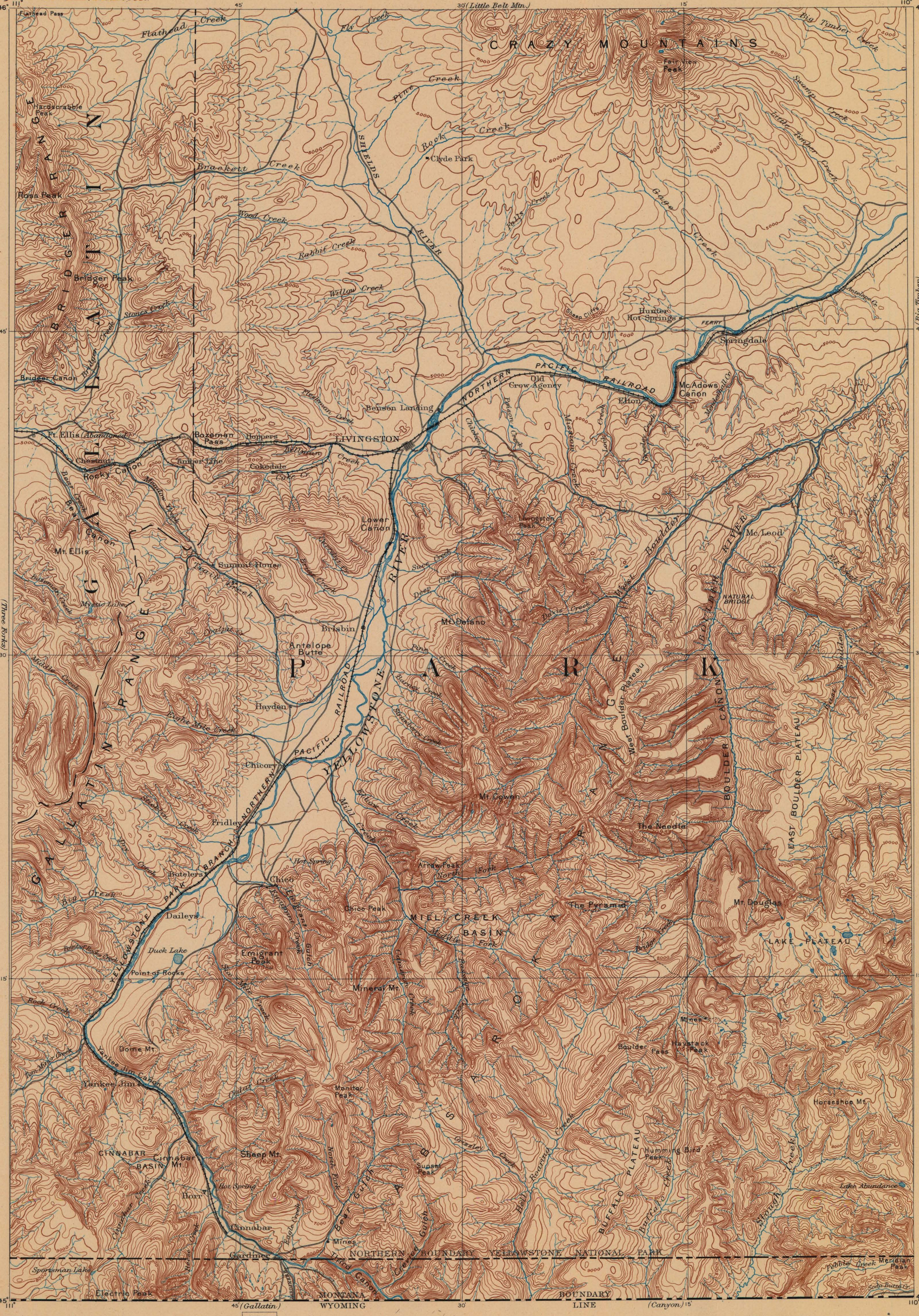
ARNOLD HAGUE,
Geologist in Charge.

January, 1893.

U.S. GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR.

TOPOGRAPHY

MONTANA
LIVINGSTON SHEET



(Fort Logan) (Big Snowy Mtn.) (Little Belt Mtn.) (Big Timber) (Three Forks) (Gallatin) (Canyon)

LEGEND

RELIEF *(printed in brown.)*

- 11352 — Figures *(showing exact heights above mean sea-level.)*
- Contours *(showing height above sea, horizontal form and steepness of slopes of the surface.)*

DRAINAGE *(printed in blue.)*

- Rivers
- Creeks
- Intermittent streams
- Lakes and ponds

CULTURE *(printed in black.)*

- Towns
- Railroads
- Bridges
- Tunnels
- Roads
- Trails
- County lines
- State lines

Henry Gannett, Chief Topographer.
A.H. Thompson, Geographer in charge.
Triangulation by E.M. Douglas and J.H. Renshawe.
Topography by { Northern Transcontinental Survey. Frank Tweedy and W.H. Leffingwell.
Surveyed in 1886-7.

N.T.S
Tweedy
W.H.L.

Scale $\frac{1}{250,000}$

0 2 4 6 8 10 12 Miles

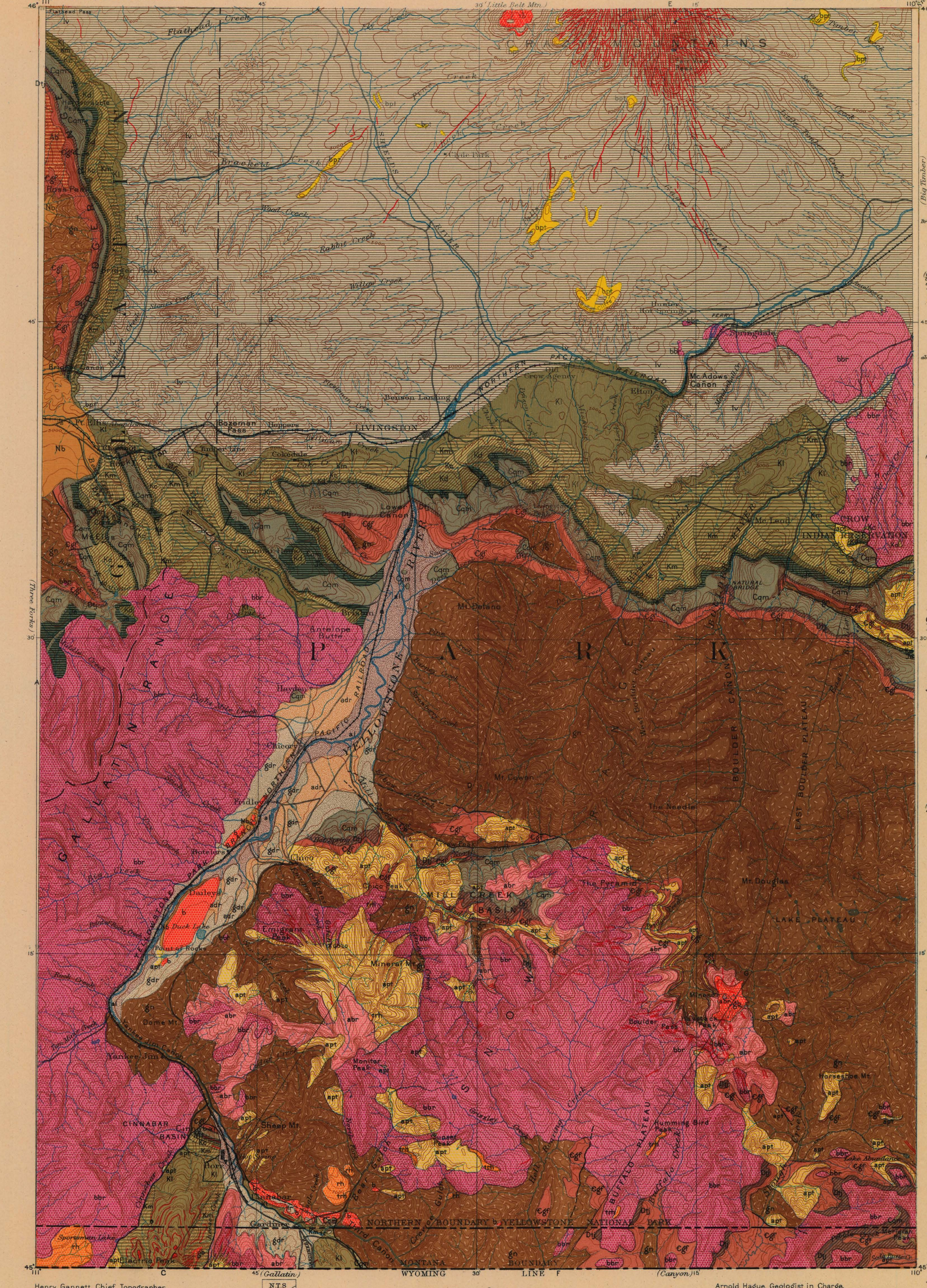
Contour Interval 200 feet

Edition of July 1893.

U.S. GEOLOGICAL SURVEY.
J.W. POWELL, DIRECTOR.

AREAL GEOLOGY

MONTANA
LIVINGSTON SHEET



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Geology by Joseph Paxson Iddings and Walter Harvey Weed.
Surveyed in 1890-1.

LEGEND

SUPERFICIAL

PLEISTOCENE
- tr — Travertine (Hot Spring deposit. Lime)
- al — Alluvium (Brick clays)
- adr — Assorted glacial drift
- gdr — Glacial drift

SEDIMENTARY

NEOCENE
- Nb — Bozeman lakebeds (conglomerates and clays. Brick clays-Polishing materials)

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- lv — Livingston formation (including probable Fort Union beds. Lower part conglomerates, sandstones and tuffs largely of andesitic materials. Upper part sandstones and clays. Lignites and Building stone)

CRETACEOUS
- Kl — Laramie formation (Sandstones and clays, containing from 3 to 6 workable coal seams-Building stone)
- Km — Montana formation (Fox Hills sandstone. Pierre shales)
- Kc — Colorado formation (Niobrara limestone and shales. Benton shales)
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JURA- ?
- Je — Ellis formation (Arenaceous limestone. Myacites limestone and quartzites)

CARBONIFEROUS
- Cqm — Quadrant quartzite Madison limestone

DEVONIAN
- Dtj — Three Forks shale Jefferson limestone (possibly including Silurian at base)

CAMBRIAN
- Єgf — Gallatin limestone and shales. Flathead quartzite and shale.

ALGONKIAN
- Ab — Belt Beds (conglomerates sandstones and arenaceous limestones)

IGNEOUS

- b — Basalt
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- Dikes and sheets (of various rocks)
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CRYSTALLINE

ARCHEAN
- gn — Granite, gneiss and schist

U.S. GEOLOGICAL SURVEY
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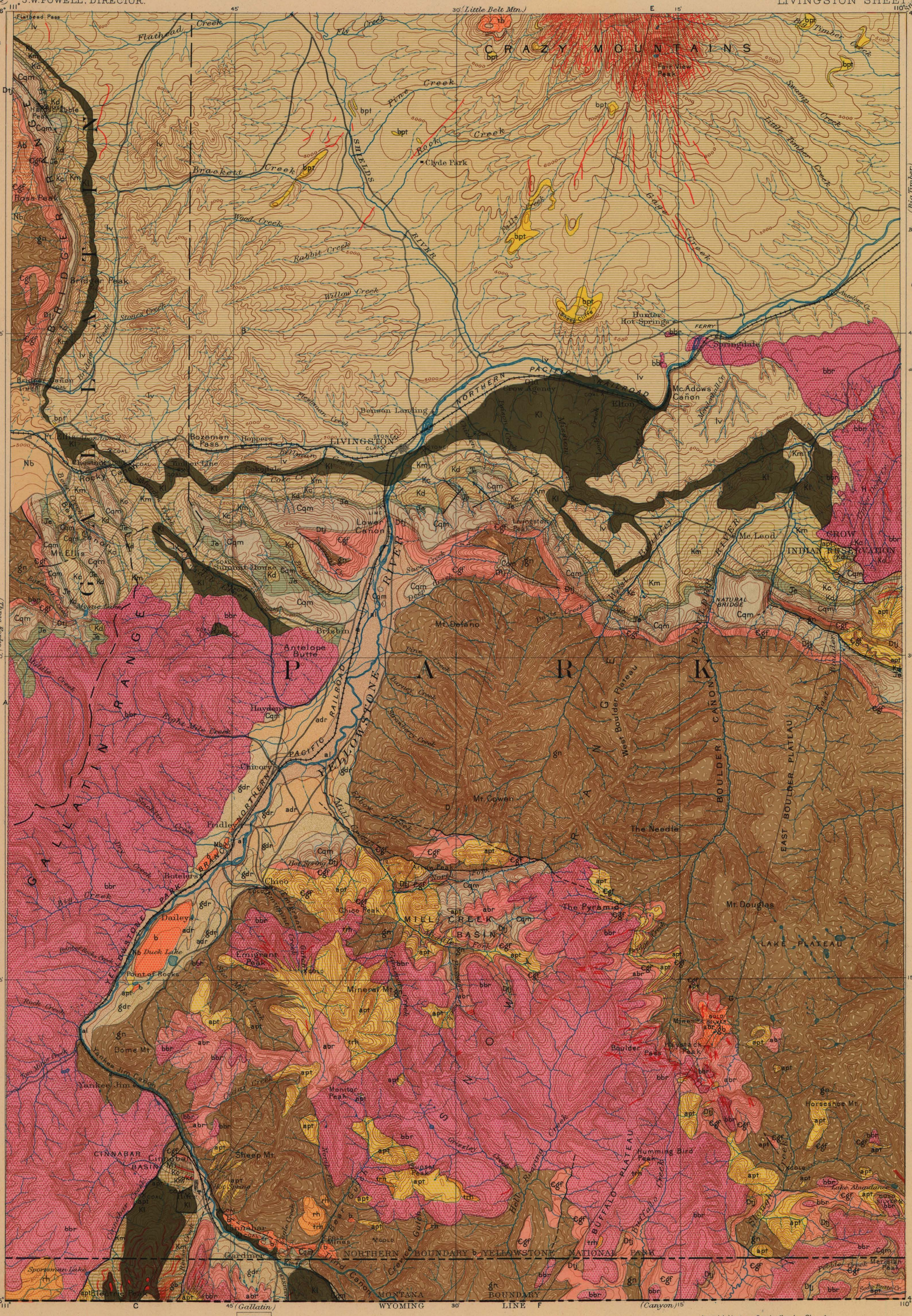
ECONOMIC GEOLOGY

MONTANA
LIVINGSTON SHEET

⚒ × Mines and Prospects

Known productive areas

Coal



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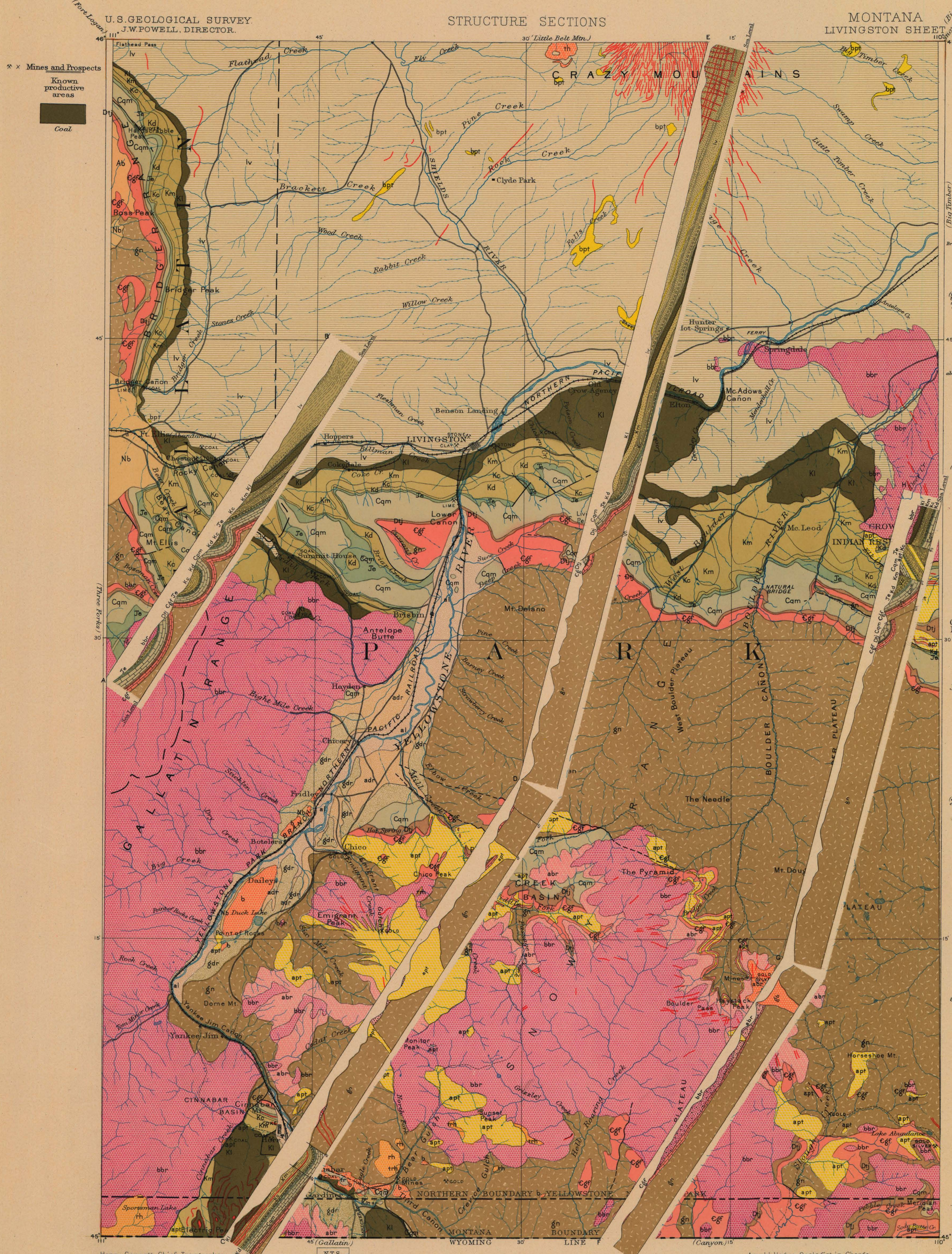
STRUCTURE SECTIONS

MONTANA
LIVINGSTON SHEET



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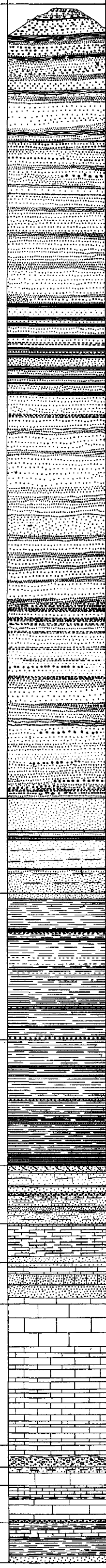
COLUMNAR SECTION.

SECTION AT YELLOWSTONE CANYON NEAR LIVINGSTON.

Period.	Formation Name.	Formation Symbol.	Columnar Section. Scale 1000 feet = 1 inch.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CRETACEOUS? Note.—The fossils of the Livingston formation do not yet afford conclusive evidence of its age. It is most nearly allied with the upper Cretaceous but is separated from the Laramie by an unconformity and a period of volcanic activity with mountain development.	Livingston formation (including 1400 feet of beds, probably of Fort Union age).	lv		1400	Light gray or yellow friable sandstone, thickly bedded and cross-bedded, alternating with gray silty shale holding intercalations of hard lamellar sandstone and lenses of blue limestone, which weather in concentric forms. Plant remains and fresh water shells occur in the strata.	Generally low but rough country, in which the sandstones form low combs and ridges, and the shale belts level plains.
				7000	Sandstone with beds of conglomerate formed of water worn pebbles six inches or less in diameter, mainly of volcanic material, but including fragments of all earlier formations.	Rough hills and broken country, generally barren and unfit for cultivation.
					Alternating beds of sandstone and crumbly green or purple shale.	Undulating country, the sandstones forming low ridges. This part of the series generally forms valleys.
					Poorly assorted sandstone and grits of volcanic debris	Long ridges or combs projecting above barren slopes, which are generally smooth.
					Local intercalations of volcanic breccias, agglomerates and tuff beds, representing volcanic eruptions.	
					Dark brown or green sandstone containing plant remains with local beds of conglomerate.	Ridges formed of the sandstone beds, the outcrops being often concealed by debris.
CRETACEOUS	Laramie sandstone.	Kl		1000	Light gray or yellow sandstone with shale beds and workable seams of coal. Plant remains with brackish water shells.	Bluffs or ridges rising above gentle slopes of Montana shale.
	Montana shale.	Km		2900	Leaden gray, arenaceous shale with thin beds of sandstone. Marine fossils.	Foot-hill country, sandstone ledges projecting above smooth grassy slopes of shale belts.
	Colorado shale.	Kc			Calcareous shale with interbedded sandstone. Marine fossils.	
					Black bituminous shale.	
	Dakota sandstone.	Kd		600	Quartzite underlain by sandy shale passing into conglomerate at the base. Fresh water fossils in limestone near the top.	Prominent foot-hill ridges.
JURATRIAS	Ellis limestone.	Je		460	Thinly bedded impure limestone. Marine fossils of Jurassic types.	Narrow valleys between mountain slopes and foot-hills.
CARBONIFEROUS	Quadrant quartzite.	Cq		400	Quartzite alternating with thin beds of limestone passing into massive limestone at the base.	Mountain slopes.
	Madison limestone.	Cm		1500	Very massive, heavily bedded, structureless limestone, generally crystalline and of a light gray color.	Bold craggy mountain summits.
					Thinly bedded and fissile, dark gray limestone. Abundant marine fossils.	Mountain masses.
DEVONIAN	Three Forks shale.	Dt		240	Alternating shale and limestone containing fossils.	Gulches and sags.
	Jefferson limestone.	Dj		200	Dark colored, arenaceous limestone, passing into massive limestone at the base.	Bold, bluff wall.
CAMBRIAN	Gallatin limestone.	€g		410	Alternating shale and thinly bedded limestone, resting upon massive mottled limestone, passing into limestone conglomerate at the base. Abundant fossils.	Steep slopes, cliffs and bluffs.
	Flathead formation.	€f		425	Crumbly shale and shaly limestone with basal quartzite.	Depressions and low ridges.