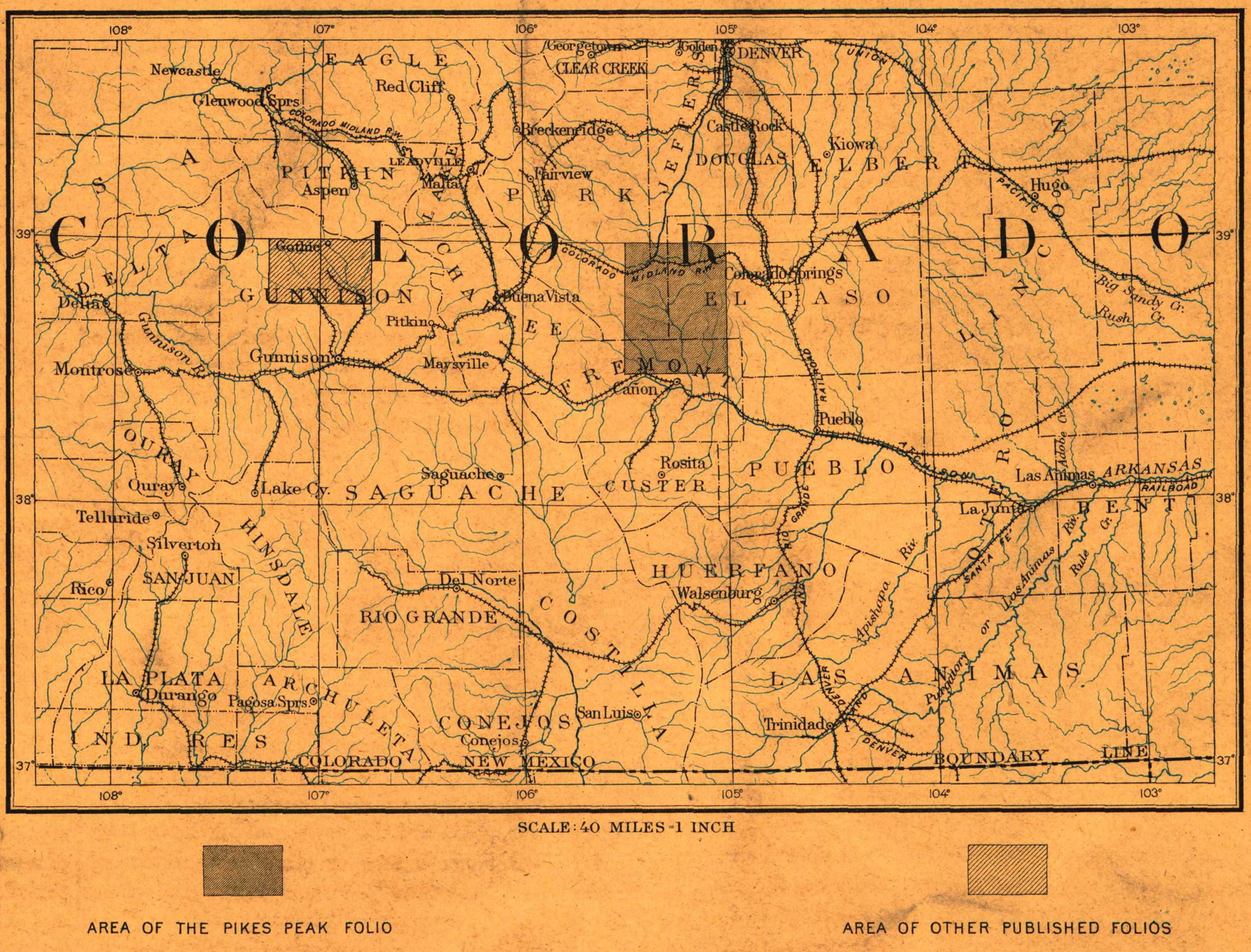
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

PIKES PEAK FOLIO
COLORADO

INDEX MAP



■ AREA OF THE PIKES PEAK FOLIO

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FOLIO 7 LIBRARY EDITION PIKES PEAK

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:

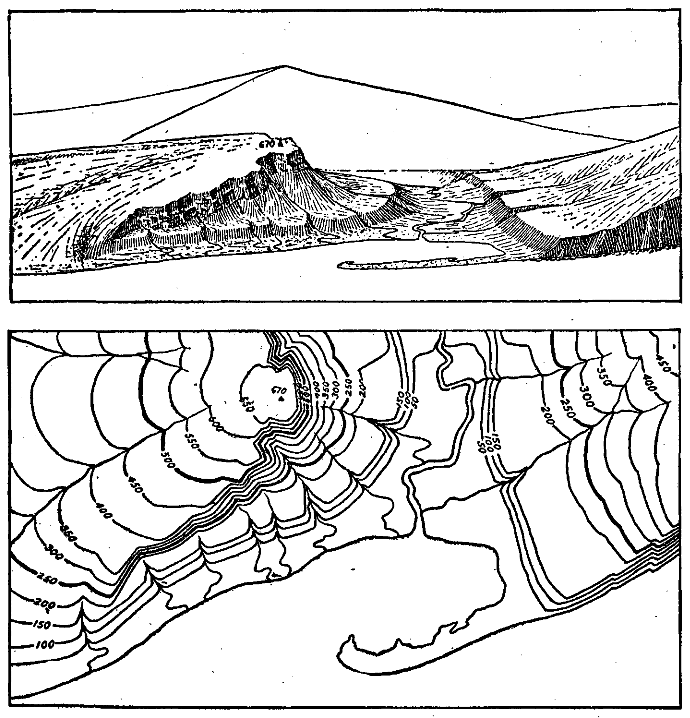


Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

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 reëntrant 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	Ꞓ	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:

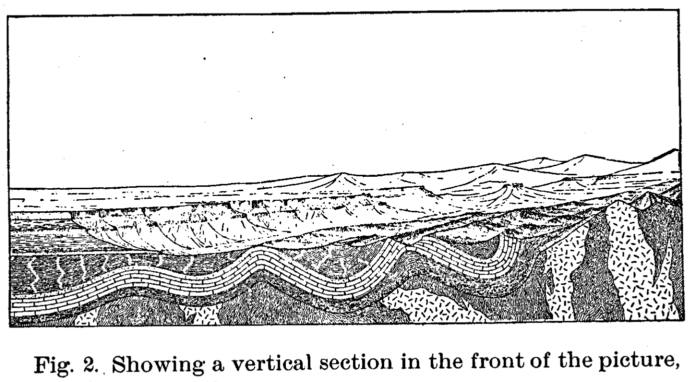


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

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:

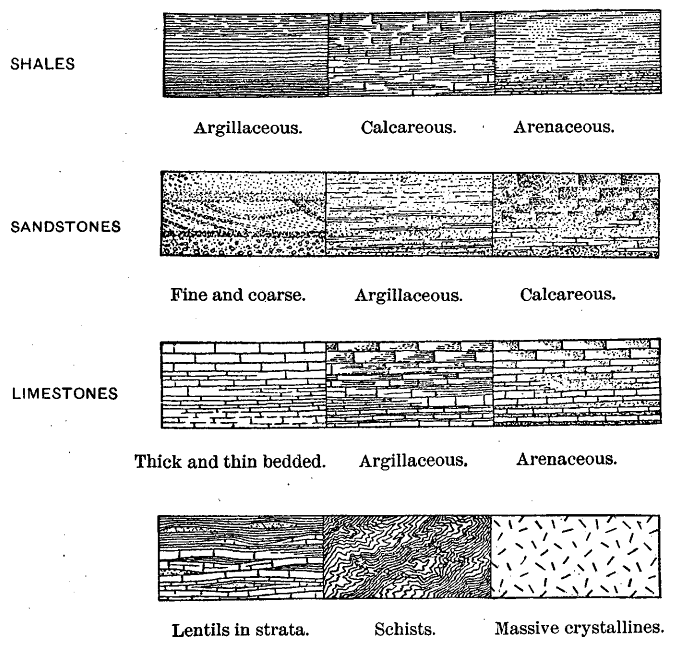


Fig. 3. Symbols used to represent different kinds of rocks.

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.

DESCRIPTION OF THE PIKES PEAK SHEET.

GEOGRAPHIC RELATIONS.

The Pikes peak atlas sheet embraces the territory between the meridians of 105° and 105° 30′ west longitude, and the parallels of 38° 30′ and 39° north latitude. This area is 34·5 miles long, north and south, and 27 miles wide, and hence contains 931·5 square miles. It includes portions of Fremont, El Paso and Park counties.

TOPOGRAPHIC FEATURES.

Relief.—The area is almost wholly mountainous. On the eastern side is the crest of the Colorado range, including its culminating point, Pikes peak, and including also a part of the rather abrupt southern end of this range as it dies out en echelon. The central and western portions of the district form essentially a high plateau, penetrated on the south by the narrow valley which will hereafter be referred to as Garden park bay. The most prominent topographic feature of the region is the mass of Pikes peak, which rises to an elevation of 14,083 feet above sea level. On the east the descent of 8,000 feet to the plains takes place within eight miles, but is broken by many smaller mountain and foot-hill masses lying in the area of the Colorado Springs sheet. West of the peak the descent is rather abrupt to a general plateau between 8,500 and 10,000 feet altitude, which stretches westward for many miles, and is practically the level of the great South park.

The relation of the Pikes peak elevation to this plateau is brought out by the profile section B-B, extending from Pikes peak to the Platte river canyon, shown on the structure section sheet of the folio.

To the south the plateau is deeply scored by many canyons of comparatively recent erosion, which cut nearly to the level of the plains, at about 6,000 feet. The greatest elevation is that of Pikes peak, and the least that of Oil creek, as it crosses the southern boundary of the area at about 5,500 feet above sea level.

Drainage.—The drainage of the district is by tributaries of the South Platte and Arkansas rivers. In the northwestern corner the South Platte river issues from South park on the line of the map and cuts its way through the Eleven Mile canyon, curving in its course from east to north. Almost the entire northern third of the district is drained into the Platte, either directly, by Twin creek, or through branches of Trout creek which passes north through Manitou park.

In the northeastern corner of the map area is the head of Fountain creek, which courses south of east to its debouchure upon the plains at Manitou Springs, and thence finds its way southward to the Arkansas. The remaining two-thirds of the area is drained by direct tributaries of the Arkansas, the most important of which are Oil creek, Beaver creek and Currant creek. These are the streams which have cut the numerous deep canyons in the granite plateau. The Royal Gorge of the Arkansas approaches at its upper end to within one mile of the southern map line, south of West Eight Mile park.

Culture.—In spite of its proximity to the earliest settled portion of Colorado the district of the Pikes peak sheet had no important settlement until the mines of Cripple Creek were discovered. Along the line now followed by the Colorado Midland railroad ran the old stage line from Colorado Springs through South park to Leadville, and Florissant has long been a small village.

The plateau region is arid but affords extensive grazing lands for cattle. In Garden park and at certain places in the upper valley of Oil creek, and in Currant creek, there are bottom lands which through irrigation yield good crops of hay, and on Beaver creek in the area of the sedimentary rocks is a small district where fruit is easily grown.

The northern and western slopes of Pikes peak were at one time thickly covered with a luxuriant forest of spruce which many years ago was largely burned over and is now replaced by a dense growth of aspen. Over the general plateau country there is a struggling growth of spruce and of piñon pine, and in the lower ground of Garden park and along the base of the mountains piñon pine, cedar and scrub oak are quite uniformly but sparingly present. Various species of cactus and other plants of dry climates are found in the lower portions of the area.

DESCRIPTION OF ROCK FORMATIONS.

As a preliminary to a general sketch of the geology of the Pikes peak district it is necessary concisely to describe the various rock formations entering prominently into its constitution and recognized upon the map. They belong to the three great classes of igneous, sedimentary and metamorphic rocks, but will not be treated in strictly corresponding groups because the gneisses, the leading metamorphic rocks, are so intimately connected with the granites that these two can best be described together. The later igneous rocks are so far removed from the granites in time and conditions of origin that they may well be considered by themselves.

GRANITE AND METAMORPHIC ROCKS.

GRANITE.

General statement.—The southern portion of the Colorado range is mainly made up of granite and of the gneissoid rocks derived from it. There are several types which are plainly products of different intrusions, and many varieties whose significance can be determined only after long study of a large field. The facies, or local variations within a given rock body, often differ more among themselves than masses of independent origin. The chemical composition of most of the different granites is nearly the same, and the marked differences arise chiefly from differences of color or else from variation in structure due to conditions of consolidation.

Within the area of the Pike's peak sheet granite appears in many more or less marked varieties, but as these are not differentiated on the map, and as, indeed, the relationships of most of them were not worked out, a characterization of only the most important types must suffice. There are two types which are especially prominent as occurring in very large bodies, and contrasting distinctly in structure:

The Pikes peak granite.—The mass of Pikes peak is principally made up of a single granite type, belonging to what is apparently one great body extending for many miles in all directions. In the summit pyramid, above 13,000 feet, there are several intersecting types. The main granite type is a very coarse grained biotite-granite, or granitite, in most places of pronounced red color due to a pigment of hydrous iron oxide which conspicuously impregnates the feldspars. Its main constituents are the potash feldspars, microline and orthoclase, often intergrown after the manner of perthite, with plagioclase, quartz and biotite. Zircon, apatite, allanite, rutile and other rare accessory minerals are present with more or less constancy.

Feldspar is the strongly predominant element of the rock and the variations in its development cause the principal structural modifications. Sometimes the grains of quartz and feldspar are of nearly the same size but ordinarily the feldspar grains are the larger. By a formation of distinct crystals, often very sharply defined and sometimes as much as three inches long, though usually less than half that size, there arises a porphyritic structure and the rock becomes a granite-porphyry. This type is well developed at Raspberry mountain, and in other places. Biotite occurs in single leaves, large or small, or in clusters of small flakes which have the effect of large ones.

In the Pike's peak type proper, biotite is quite subordinate, but in the region on either side of the Platte river, and in several places in the southwestern portion of the districts, a large increase in amount of black mica greatly changes the appearance of the rock.

The fine grained granite.—In marked contrast to the Pikes peak type is a characteristically fine and even grained reddish or pinkish granite which is poor in mica; while its particles are large enough to be easily distinguished by the naked eye, it derives its general aspect from the abundant feldspathic element. This rock varies little in structure and seldom in mineral constitution. It is sometimes deep red and in other places pale pink. In the summit cone of Pikes Peak, where its dikes cut the coarser variety, an admixture of hornblende causes a darker tone.

This fine grained granite cuts the coarser grained in many dikes, and also forms large areas of uniform rock in the plateau region west of Pikes peak. Apparently the greater part of this type belongs to one period of eruption, but it is by no means certain that all the dikes of fine grained granite found in the coarser rock belong to one period.

Minor granite types.—On the western and southern slopes of Pikes peak, generally above 11,500 feet, there are several masses of a porphyritic granite whose constituents are the same as in the main type, but both red feldspar and quartz are developed in crystals lying in a distinctly granular mass of the same minerals. The feldspars are never so large as in the Pikes peak type, and transitions are rare. This variety seems to represent a granite cutting the main type.

Certain areas contain a fine grained granite which is almost white and its feldspars are more largely plagioclase than in the main fine grained type. This seems to be a distinct type but it was not found in connection with the more common fine grained granite to which it is related.

Another variety of undetermined importance occurs in the hills north of the Platte river. It is characterized by a development of the pinkish feldspar in small crystals not much larger than the irregular grains of quartz and feldspar about them. This rock has quartz and biotite in about the same development as the common fine grained granite but its eruption appears to have occurred after the movements which produced gneissoid structure in all other types of the district, and hence to be distinct.

Coarse granitic dikes and veins.—All the granites are traversed by dikes of very coarse grained granite usually designated as pegmatite, in which microcline, orthoclase, albite, oligoclase, quartz, biotite, muscovite and occasionally other minerals are developed in large individuals and are often segregated somewhat in different parts of the dike. These pegmatite dikes are abundant only in the region near the Platte river.

The fine crystals of Amazonstone, smoky quartz, topaz, phenacite, and other rare minerals which have made the Pikes peak region famous, have been found most abundantly some miles southeast of the summit of the peak within the area of the Colorado Springs sheet. But some of the largest and finest specimens of these four minerals have been obtained from Crystal peak, north of Florissant. These minerals occur in vein-like masses similar to the pegmatite dikes, except that a free space of variable relationship to the vein material has allowed development of crystal faces. The presence of fluorite, cryolite, topaz, etc., testifies to the presence of fluorine in large amount during the formation of these vein minerals. Cryolite is not found within the area of this sheet. It appears as a local filling of residual spaces in certain veins, after the formation of the other minerals. [See 6 in the list at the end.]

METAMORPHIC ROCKS.

Relation of gneiss to granite.—Nearly all of the rocks of the Pikes peak district which may be called gneisses are practically mineralogical equivalents of the granites above described but possess a more or less marked foliated structure. Muscovite is the only mineral of much importance not characteristic of the granites. The massive granite is so frequently found grading insensibly but rapidly into foliated gneiss that there can be no question of the derivation of most of the gneisses from the granites under the influence of a great pressure.

The plainest instance of the transformation of granite into gneiss is exhibited by the coarse porphyritic granite, whose large feldspar crystals, with sharp angles, become gradually distorted, crushed and drawn out into "eyes" or flat lenses, with mica leaves wrapped about them. This change can sometimes be seen within two or three feet. In the even grained granites the foliation is marked by the parallel position of the mica leaves, muscovite being commonly associated with biotite. The intermediate structural stages are so abundant that the expression "gneissoid granite" is applicable to the rock of considerable areas.

Gneisses of doubtful origin.—Occurring with certain of the supposed Algonkian quartzites, or as separate inclusions in granite, are gneisses which are not demonstrably derived from granite. These are usually fine banded rocks, which are rich in mica, or show a marked alternation of dark and light colored minerals. Some of them have a development of fibrolite and almost grade into some of the Algonkian quartzites impregnated with secondary minerals. It is quite probable, indeed, that the fragments in granite represent products of metamorphism of Algonkian strata, and also the true Archean gneisses upon which the Algonkian beds were deposited.

Schists.—Rocks possessing so perfect a degree of foliation that they may be properly termed schists are of very subordinate development in this district. In some places on and near certain planes the gneissic structure gives way to a fine schistosity, muscovite replacing feldspar, and a mica-schist results. But the most pronounced schists are found as inclusions in granite, notably in the Cripple Creek district. These seem to represent earthy Algonkian quartzites metamorphosed by a great development of mica, or of fibrolite.

Chloritic or amphibolic schists locally result from the squeezing of dikes or small masses of ancient basic igneous rocks, as may be seen near Rocky, and in the southwestern corner of the district.

SEDIMENTARY FORMATIONS.

ALGONKIAN PERIOD.

The distinctly stratified quartzites and allied rocks found as inclusions in granite and gneiss are obviously the oldest sedimentary rocks of the district. They are at present known only in detached masses and are therefore not given a formation name. The largest and most homogeneous of these masses is that shown in Wilson park. Here there is exposed a section nearly 4,000 feet in thickness of white or bluish gray quartzites, standing on edge and exposed on the strike for about 5 miles. They are cut off on the southwest by granite, and at the northeast pass under the sedimentary rocks of Garden park. Granite dikes penetrate them at various places. A narrower belt of quartzite appears in Cooper mountain, east of Garden park, trending northwest.

Another important mass is that forming a ridge west of Florissant, a portion of which is known as Blue mountain. The ridge consists of fibrolitic quartzite with a small and variable amount of feldspar. This mass is also cut by granite dikes and is entirely surrounded by granite.

On the northern border of the district, near Rocky, is an area of quartzites and schistose rocks some of which contain pyroxene and garnet. These rocks are cut by granite but the area widens to the northwest, beyond the region visited, and it may expand in that direction to represent the formation in situ where it is not entirely enclosed by granite. Thousands of much smaller fragments of quartzite and fibrolitic or micaceous schists are included in granite and gneiss of the district.

The base of the known Paleozoic section in Colorado is an upper Cambrian quartzite which in the Colorado range rests upon the granite and gneiss containing these quartzite inclusions. In the light of present knowledge concerning pre-Cambrian sediments in the West it is deemed better to refer the included sedimentary rocks to the Algonkian rather than to assume that the period of their deposition, as well as that of the granite eruptions, and still further that of metamorphism, producing the gneisses, are all within the lower and middle Cambrian.

CAMBRIAN PERIOD.

No Cambrian formation is represented upon the map, although it is probable that a small thickness of quartzite and of cherty limestone below the Manitou Silurian limestone belong to that period. In Manitou park and near Manitou Springs brachiopod shells, *Lingulepis* and *Obolella*, have been found in quartzites beneath the Manitou limestone, and the cherty limestone at the base of the series in Garden park has yielded a trilobite, *Ptychoparia*. These forms indicate upper Cambrian deposits, but the extreme thinness of the beds in question and their variable local development makes their representation on the map impracticable and they are therefore included with the Manitou limestone.

SILURIAN PERIOD.

The Silurian section of the upturned zone between Canyon City and Garden park has been studied in detail by Mr. C. D. Walcott, and divided into three important formations, distinguishable by their rich invertebrate faunas and also by stratigraphic data, to which he has given the names here used. [8.]

The Manitou limestone.—This is the lowest Silurian formation. In Garden park it consists of fine grained, pink or reddish dolomite, less than 100 feet thick, and contains *Ophileta*, *Camarella*, and a few other invertebrate fossils characteristic of the lower Silurian formation in the section at Manitou Springs and in Manitou park, whence the name is derived. This limestone is best seen in the upper part of Garden park. On the slopes of the Colorado range to the east the formation has been much eroded, and it is wanting in many places east of Eight Mile canyon.

The limestone below the Fountain beds in the northeastern corner of the area is connected directly with the typical locality at the north end of Manitou park, but the steeply upturned beds are much thinner than to the north, partly through shearing, partly by erosion preceding the Fountain period. The formation is not dolomitic in this vicinity.

The Harding sandstone.—This very characteristic formation is made up predominantly of fine and even grained, saccharoidal sandstone in alternating banks of light gray and pinkish or variegated colors, with a few bands of dark red or purplish sandy shale. The maximum thickness is about 100 feet. The lower part is sometimes calcareous and locally develops into a thin, fine grained dolomite.

This horizon is characterized by numerous plates and scales of ganoid fishes and by a chordal sheath of a selachian form. It carries also a rich invertebrate fauna indicating close correlation with the lower Trenton of New York. The fishes of the Harding formation are the oldest known, and belong to types not elsewhere found below the Devonian.

The Harding sandstone is not found in Manitou park, or at Manitou Springs, and has not been identified at any other locality, but similar fish remains have been discovered by Mr. G. H. Eldridge in Gunnison county, Colorado, in lower Silurian strata not yet differentiated in a manner corresponding to the Garden park section. In Garden park the Harding sandstone rests with apparent conformity on the Manitou limestone, but on the southeastern face of the range the latter is more or less eroded, so that the Harding rests locally on the basal cherty limestone (Cambrian), or even on granite. On the western line, toward Canyon city, the Harding beds rest on gneiss, apparently by overlap. The name given the formation is that of a stone quarry near Canyon city, affording excellent exposures.

The Fremont limestone.—Succeeding the Harding sandstone with apparent conformity there occurs a bluish gray or pinkish dolomite of uneven grain, sometimes arenaceous, which gives rise to very rough weathered surfaces. It forms the protecting cap of the gently inclined mesas at the north end of the Garden park bay, and of the steeper dip slopes south of West Wilson creek and north of Six Mile park. There are often small caverns and hollows in the cliff faces of this rock. The thickness of the limestone in Garden park is about 100 feet, but it increases southward, and near Canyon city reaches a maximum of 270 feet. This is partly through the development of an upper and highly fossiliferous member not seen in Garden park.

The Fremont limestone of Garden park is especially characterized by the chain coral *Halysites catenulatus*, and also contains a large invertebrate fauna like that of the upper Trenton of New York. Masses of chain coral two feet in diameter are not uncommon.

This limestone horizon has not been recognized in other sections of Paleozoic strata along the east base of the mountains, nor has its equivalent been found in any other part of the West. Its present limitation eastward from Garden park, on the slopes of the range, is by erosion which took place after the deposition of the Millsap limestone.

The name Fremont is that of the county containing all of the known exposures of this limestone.

CARBONIFEROUS PERIOD.

The Millsap limestone.—This formation is found only in local remnants resting upon the Fremont limestone in Garden park and along the western line toward Canyon city. It is specially well exposed in the angle between Oil and Millsap creeks and is named from this locality. The formation is now represented by about 30 feet of thinly bedded, variegated, dolomitic limestone, with a few thin sandstone layers. Chert nodules in the upper limestone layers carry casts of *Spirifera rockymontana* and *Athyris subtilita*, characteristic forms of the Carboniferous throughout the West.

The long period between the Fremont and Millsap epochs seems to have been one of elevation and erosion, for while there is seeming conformity between the two limestones in local exposures, the Millsap strata of Garden park rest upon much lower beds of the Fremont than at exposures nearer Canyon city, where an upper division of the Fremont is preserved. In lithological character the Millsap limestone is peculiar, and the few fossils thus far obtained from it have such a wide range that close correlation of these strata with those of other sections is as yet impossible.

The Fountain formation.—Under this name are included a series of red sandstones, grits and conglomerates, a part of the so-called "Red beds," found in typical development on Fountain creek below Manitou Springs, and at the head of the same stream in the northeastern corner of the Pikes peak area—hence the local name here applied. The formation in Garden park seems practically identical lithologically with that of the former area, and the same name is applied to the beds of both regions.

The beds of the upper exposures on Fountain creek belong to the basin of Manitou park. They are chiefly coarse grained, crumbling, arkose sandstones, in heavy banks showing cross-bedding. They are locally conglomeritic, mottled with gray and various light shades of red, through irregular distribution of the coloring matter. Near the base and at intervals throughout the series are very dark red or purplish layers of arenaceous shale or fine grained sandstone. The thickness of the formation near Woodland park is estimated at nearly 1,000 feet.

The characteristics above noted are also found in the lower 1,000 feet of the section of reddish sandstones and grits to the east of Manitou Springs, referred by Hayden to the upper Carboniferous, while the finer grained "Red beds" succeeding them, together with the strata of Manitou park were called "Triassic." No reason for the distinction was given by Hayden. [4.]

In Garden park the Fountain beds reach a maximum thickness of about 1,000 feet. They are heavy bedded, with much feldspathic material derived from the adjacent granite. The conglomerate layers contain many pebbles of hard Algonkian quartzites while a few limestone and chert pebbles were noted in the lower part of the series. Dark shales are less prominent than in Manitou park. The Fountain beds rest unconformably upon the edges of the entire Silurian section in Red ridge, at the upper end of Garden park, and along the southern end of the Colorado range they come in contact with the Harding sandstone. Beyond the eastern line of the Pikes peak sheet they are usually found to abut against granite or gneiss.

No fossils are known in this formation and it is assigned to the Carboniferous from the fact that in many other parts of Colorado, notably on the Arkansas river 50 miles westward, there is a great series of similar red sandstones and grits of Carboniferous age, as proved by fossils contained in thin limestone strata occurring at various horizons in the section. While a greater part of the "Red beds" series east of the Colorado range has been considered "Triassic" no fossil or other definite evidence has as yet been found to show the correctness of such a conclusion. It is deemed more probable that the lower part at least of these "Red beds" belong to the Carboniferous, than that the whole complex is Triassic.

JURATRIAS PERIOD.

The Morrison formation.—The earliest Mesozoic sediments are prevailingly greenish, pinkish or gray shales and marls. Sandstone occurs at the base and is also intercalated at numerous horizons in the upper part of the section with varying development. The total thickness of the Morrison formation in Garden park is about 350 feet. In a sandstone horizon about 100 feet from the top of the series has been found a large vertebrate fauna belonging in this locality especially to the Dinosauria, many forms of which have been described by O. C. Marsh. Fresh water shells associated with these remains indicate the character of the sea in which the rocks were deposited. Gypsum is locally developed and becomes prominent to the east. A thin limestone often forms the base of the formation. The name is given from the classic locality at Morrison, near Denver, where the first gigantic Dinosaurs from this formation were obtained.

The Morrison strata rest with apparent conformity upon the Fountain grits in the main foot-hill section, but in Twelve Mile park and in the higher plateau region to the north they lie directly upon granite. There is thus a great stratigraphic break between the Morrison and the Fountain formations the extent of which is at present unknown. A similar series of beds beneath the Dakota formation of the Cretaceous period, occurring on the Pacific slope in Colorado, has been named the Gunnison formation by Mr. G. H. Eldridge, in the description of the Crested Butte sheet.

CRETACEOUS PERIOD.

The Dakota formation.—The Morrison formation is followed with apparent conformity by about 300 feet of fine white or gray sandstone, called the Dakota sandstone, usually friable and of uniform texture. At or near the base there is usually a fine conglomerate, the pebbles of which are variously colored chert or white quartz. Midway in the series are several layers of dark shale, locally developed into pure fire clay of economic importance. Where steeply upturned the Dakota characteristically forms the capping of hogback ridges, or of gentle mesa-like slopes, as to the south of Garden park. This formation is found above the Morrison in Twelve Mile park, and in small remnants upon the granite to the north. Many fossil leaves are found in the thin shale layers at various horizons in the formation.

The Colorado formation.—The Dakota is succeeded by a series of dark or gray shales with a complex of fine limestone beds about midway in the series, and with a brownish sandstone near the top. The thickness displayed on West Wilson creek near the southern border of the map is about 500 feet. These shales represent the Benton division of the Colorado. They are succeeded by a limestone complex, the thin layers of which are characteristically separated by thinner shale seams. Above this limestone come several hundred feet of yellowish shales, more or less arenaceous, and the two divisions comprise the Niobrara formation as it is characteristically seen at many localities along the Colorado range, to the north and south. The formation is best developed in the valley of Oil creek. In Twelve Mile park both the Benton and the Niobrara seem much diminished in thickness, and in the locality called The Basin the Dakota is succeeded by limestone with but a few feet of impure shales between. Characteristic fossils of the formation are found here, but not in abundance.

The Montana.—This division of the Cretaceous is represented within the limits of the atlas sheet only in Twelve Mile park, where there is a thickness of a few hundred feet of characteristic gray or yellowish brown arenaceous shales, containing an abundance of clay ironstone concretions. It is probable that only the Pierre or lower division of the Montana is represented in this park.

EOCENE PERIOD.

The Florissant lake beds.—The largest post-Cretaceous lake basin of the district is that about Florissant. As shown by the map this lake occupied a long, narrow depression now traversed by Twin creek and its southern tributary, Grape creek, and extended for varying distances up some of the side gulches. Its length was about 15 miles and its width very irregular, but its former area cannot have been much greater than that of the beds still preserved.

The deposits in the Florissant lake were almost wholly of volcanic ashes which were probably showered upon its waters, forming soft and crumbling tuffs and mud shales. The total thickness of strata now preserved is only about 50 feet, mainly in thin layers of very fine grain, alternating every few inches with coarser ones, while heavier banks several feet in thickness occur in some places.

The predominant material is andesitic in character, with detritus of basalt and rhyolite, and probably belongs to the earliest eruptions of the volcanic center which lies westward of the map area. Dark basaltic breccia, and remnants of rhyolitic flows rest upon the Florissant tuff at many points.

The conditions under which the Florissant tuff was deposited were highly favorable to the burial and preservation of the subtropical fauna and flora of the period. The insect fauna preserved is especially wonderful. Many thousand specimens have been collected since the discovery of the beds and although the material has been but partially described it is sufficiently known to prove that no other locality in America, and but one or two in Europe can compare with Florissant in variety of insect forms preserved.

In addition to the insects there are a few birds, fishes and mollusks, and a very large fossil flora. The fossil remains agree in indicating that the climate of the period was warm, and the age of the formation is shown by them to be late Eocene (Oligocene). [5, 7.]

The High park lake beds.—To the west of Oil creek, on the granite plateau, lies High park, a small depression containing remnants of a series of local sandstones and conglomerates lying either upon granite or upon a thin rhyolite flow. The conglomerate is characterized by pebbles of the extremely hard Algonkian quartzite together with some of granite and gneiss. No fossils are known from these strata and they appear to be older than the adjacent volcanic breccia, as they contain no debris of such material. In the hills east of High park the conglomerate is seen between rhyolite and phonolite flows. A very small remnant of the High Park conglomerates is present on the rhyolite sheet capping Red ridge, 500 feet above the present level of High park.

The Alnwick lake beds.—In the valley of Oil creek about Alnwick is a local lake basin confined to the present valley of Oil creek, and its western tributary West Four Mile creek. The deposits in this lake were fine grained sandstone and conglomerate, among the pebbles of the latter being representatives of the volcanic series to the west. This lake was therefore apparently younger than that of High park. No fossil remains have been found in the deposits.

IGNEOUS ROCKS OTHER THAN GRANITE.

ANCIENT DIKE ROCKS.

Diabase and syenite.—The granites and gneisses of the Colorado and Wet Mountain ranges are cut by a great many dikes of diabase and syenite, which are not known to penetrate the Cambrian or later sediments, and hence probably belong to a very ancient period of intrusion.

A great majority of these dikes are of a dense dark green or black trap rock, a typical diabase. Only in a few observed cases is the grain of the rock coarse enough to permit recognition of the augite and plagioclase by the naked eye. The petrographical structure technically called ophitic is commonly well developed. Some of the dikes are rich in olivine.

Far less abundant than diabase are dikes of syenite. These are usually reddish in color, and consist of orthoclase, plagioclase, hornblende and biotite in variable proportions. A gradation to diorite is shown by a preponderance of plagioclase in some of the dikes.

The dikes of this series are most numerous in the vicinity of the Arkansas river and are particularly well exposed in the walls of the Royal Gorge and adjoining canyons. One distinct diabase dike is exposed in the streets of Cripple Creek. The dikes are usually very narrow and the scale of the map does not allow of their representation upon it.

The character of many of the diabase dikes is obscured by the paramorphic change of augite into hornblende and in zones of shearing the dike rocks are locally altered into amphibolitic or chloritic schists.

BASIC BRECCIA AND AGGLOMERATE.

Occupying about 75 square miles of the western portion of the district is a dark volcanic breccia or agglomerate made up of several allied types of basic igneous rocks. It forms a geologic unit by virtue of its mechanical constitution as a bedded aerial formation, building up mountain masses 2,000 feet and more in height upon the granite plateau.

Mechanical constitution.—The fragmental formation in question has a nearly horizontal bedded structure varying in distinctness in different localities. In texture it ranges from fine grained tuffs to irregular and chaotic mixtures of large and small fragments. Certain layers are fine grained and well stratified but as a rule the bedding is rude and becomes prominent only in large exposures. The structure is most clearly seen in Saddle mountain, The Castle, and McIntyre mountain north of West Four Mile creek, whose masses are chiefly made up of this material.

The greater part of the formation consists of heavy banks of agglomerate in which large and small fragments are promiscuously mingled. In some places the larger fragments are much rounded and in others they are angular. The fragments represent compact and vesicular rocks of various allied types in irregular association. There is no evidence that the strata were assorted by water and the constitution of the mass is that which is characteristic of accumulations about great centers of violent and repeated volcanic outbursts.

The agglomerate is penetrated by numerous narrow short dikes of compact basalt, and the same rock in local intruded sheets causes benches in several mountain masses. These small bodies could not be represented upon the map. They are especially abundant in Saddle mountain and the Castle.

The greater part of the agglomerate is soft and crumbling. An exception to this rule is the hard bank of dark breccia forming the summit of The Castle. The dikes and sheets of basalt in certain areas have protected the soft agglomerate from erosion. Through decomposition and weathering the complex has usually acquired a characteristic reddish brown or purplish color.

Petrographical character.—The lower part of the agglomerate or breccia is entirely made up of dark volcanic rocks belonging to a group on the line between basalt and andesite. They contain pyroxene and olivine in varying amounts but are never so rich in these constituents as the normal basalts cutting the breccia in dikes. The olivine is replaced to a large extent in some of the rocks by the substance of undetermined character which has been called iddingsite.

The structures of the rocks of this series vary greatly. Many are vesicular or scoriaceous while others are dense. The groundmass is prominent in all varieties and granular types have not been observed.

In the upper part of the complex more distinctly andesitic types appear in which olivine is replaced by hypersthene, and some normal augite-andesites are found. Fragments of trachyte and of hornblende-andesite are also mingled with the basic rocks in the upper beds of McIntyre mountain, and in the district south of High creek.

In the mesa of the southwestern corner of the district are several thin flows of olivine-bearing andesite similar to the fragments of some portions of the agglomerate.

MASSIVE ANDESITE.

The rocks included under the general term andesite upon the map are of many mineralogical varieties and occur in great abundance as dikes cutting the basic breccia or as sheets resting upon it. But some of the masses may be older than the breccia, for the relationship is not always clear. These andesites may be divided into two classes, those characterized by augite, and those containing hornblende and mica.

Augite-andesite.—This type forms a group of massive rounded hills at the head of West Four Mile creek and constitutes the main mass of Cover mountain. The rock is compact, and porphyritic, with abundant crystals of plagioclase and augite, and some of biotite and hornblende. The groundmass is almost equal in amount to the large crystals and is very fine grained, but holocrystalline. It is plainly a less basic rock than the pyroxene-andesites of the breccia.

Hornblende- and mica-andesites.—Under this heading are included many rocks varying greatly in the relative and absolute amounts of hornblende, biotite and augite present in more or less distinct crystals. They occur in dikes cutting the augite-andesite as well as the basic breccia, and are also found as sheets and irregular masses.

Usually plagioclase, hornblende and biotite are prominent in distinct crystals in a predominant dense gray groundmass which may contain quartz or tridymite. The andesite of the Bare hills and of the sheet about Cap rock have very few distinct crystals of any kind and the dark gray predominant groundmass carries much tridymite.

ANDESITIC BRECCIA.

Bare hills area.—The smaller of the two areas of andesitic breccia and tuff represented upon the map, situated in the Bare hills south of High park, is characterized by a fine grained, light gray tuff consisting of very light colored mica- and hornblende-andesite particles, together with variable amounts of sand and gravel derived from granite and gneiss. Larger fragments of the same rocks are locally abundant. The tuff is soft and crumbles. It is overlain and penetrated by sheets or dikes of dense andesite. It is evident that there was here a local center of eruption.

Cripple Creek district.—The principal rock of the Cripple Creek region is an andesitic breccia allied to the basic breccia of the western area in mechanical constitution, but containing less basic varieties of andesite, as far as they can now be determined. The extensive decomposition which the rocks about this eruptive center have suffered renders their full identification impossible. Details of the formation are given in the text accompanying the special map of the mining district.

RHYOLITE.

Rhyolite occurs principally in numerous small remnants of surface flows, and in all these cases it is a light colored, felsitic, thinly banded rock, containing a few small white or glassy crystals of plagioclase and leaves of biotite, with quartz in a few places. The most common color is ashen gray, but it is often white or pale pink.

In the southwest corner of the district on either side of Tallahassee creek, beds of rhyolitic tuff and breccia occur with surface flows some portions of which have a banded spherulitic structure.

TRACHYTE.

To the south of Wicher mountain is a very marked group of rounded hills formed of trachyte, and the same rock occurs in several other masses to the north and west of Cover mountain. The trachyte is massive, light gray, pinkish or white, having a few glassy sanidine tablets, numerous smaller plagioclase crystals and hexagonal leaves of biotite in a strongly predominant groundmass which possesses the typical trachytic structure, being composed of feldspar tablets and microlites, with very little quartz. These trachytes approach the rhyolites in having some excess of silica but in structure they contrast strongly with the rhyolites of the region. In some cases the trachyte is brecciated. Its fragments are also found mingled with hornblende-andesite in the upper part of the basic breccia.

PHONOLITE.

The region about Cripple Creek is specially characterized by many masses of the rare igneous rock, phonolite, elsewhere known in the United States only in the Black hills of Dakota. Phonolite is a rock allied to trachyte but characterized by the presence of nepheline in addition to alkali-feldspar, a result of its richness in soda and its low percentage of silica.

The phonolites of this district are, when fresh, dense greenish gray rocks, often with a sub-vitreous lustre. They are usually somewhat decomposed, however, and are then dull, yellowish brown, straw-colored, pink or white. Some of the rocks of the region have no distinct crystals visible to the naked eye; others have small glassy tablets of sanidine and dark green prisms or grains of ægirine, a soda-bearing pyroxene; and a few, notably a rock occurring near Altman on Bull mountain, carry large tabular crystals of sanidine, giving the rock a typical porphyritic structure.

The bleaching of a thin outer zone by weathering, and a pronounced tabular jointing, are thoroughly characteristic features of this rock type.

SANDSTONE DIKES.

A unique feature of the geology of this area is the occurrence of distinct dikes of fine grained, massive sandstone in granite. They occur on the western border of the southern portion of the Manitou park sedimentary basin, and some of the largest ones are represented upon the map. The dikes vary from a few inches to 300 yards in width, and are often connected by cross fissures. They stand nearly vertical, have a general trend from north-northwest to south-southeast, and are known in this direction, both to the north and east of the area of the map.

The material of the dikes is a uniform fine grained sand, composed almost wholly of worn quartz particles, with a very little feldspar, indurated and colored dull red by flakes of limonite. No sandstones of such uniform constitution are known in the Fountain beds, and no genetic connection can be made out between the dikes and sedimentary rocks. The dikes must be considered as injections of quicksand into fissures in granite, but the source of the sand is unknown. [9.]

GENERAL GEOLOGY.

DISTRIBUTION OF ROCK FORMATIONS.

A glance at the map shows that in general the distribution of the great rock classes corresponds to the development of certain topographic features. Thus the mass of Pikes peak and the greater part of the adjacent plateau are made up of granite and gneiss. The plateau has been modified, however, by large extrusions of igneous rocks, building up mountains upon it, mainly through true volcanic activity. Sedimentary beds are now chiefly confined to the low ground along the borders of the Plains and in Garden park bay, or to small lake basins on the plateau. The former greater extension of some of these formations is indicated by facts which will be given.

AREAS OF GRANITE AND GNEISS.

Granite and gneiss constitute the great bulk of the Colorado range throughout its length, but their genetic relationships have never been studied in detail at any point. They were indicated together upon the Hayden map of Colorado as "Metamorphic granite," and they cannot now be separated on the Pikes peak sheet because of the great complexity of their relations, requiring for their proper understanding and expression long and careful investigation.

Pikes peak.—The mass of Pikes peak above the 10,500-foot level consists of reddish granite of several types, the oldest and principal one being the very coarse grained rock named after the peak in the preceding description. This is penetrated by numerous dikes and irregular bodies of finer grained varieties, especially in the upper pyramid of the peak, above 13,000 feet.

In the granite mass are carved several glacial amphitheatres, the largest being on the west and southwest. To the north and east the peak presents very rugged slopes with smaller amphitheatres. On all the gentler slopes of the upper part of the peak the disintegration of the granite affords sufficient soil to support a beautiful alpine flora.

While no distinct gneissoid structure has been seen in any part of the Pikes peak mass there is sometimes a decided sheeting of the rocks by vertical, parallel joints, and this gives rise to the peculiar pinnacled and turreted forms called The Crags, at the northwestern extremity of the mountain. Similar projecting cliffs are seen at the ends of some of the southern ridges.

The granite plateau.—The coarse grained Pikes peak granite forms the greater part of the plateau, reaching west and north from the peak for several miles. Northward this granite type extends far beyond the limits of this sheet and it is known in large masses at Devil's Head on Platte mountain, and in the lower canyon of the Platte river, but whether it occurs as a continuous body or in separated areas is as yet unknown. The general western limit of the massive rock is an irregular line extending from the Platte river at Lake George, through Blue mountain, to the neighborhood of Alnwick and thence south of east through the Cripple Creek region. Massive granite also appears in large bodies to the west and southwest of this line, but a gneissoid structure either predominates or is locally developed in many places.

The plateau region is generally smooth and often densely wooded, but presents a number of bald knobs of massive rock which project above the general level and are visible for long distances. Dome rock is a characteristic landmark of this type.

Crystal peak, north of Florissant, is a very noticeable point, in the vicinity of which are many coarse veins in the granite, from which huge crystals of quartz and amazonstone and other feldspars have been obtained, together with many beautiful crystals of topaz and phenacite. [6.] Raspberry mountain, northwest of Pikes peak, is characterized by a porphyritic facies of the coarse granite.

District adjacent to the Platte canyon.—The mountainous area to the northwest of the Eleven Mile canyon of the Platte river presents a very complicated association of several distinct granite types containing many inclusions of Algonkian quartzites and schists, and there is also a development of gneissoid structure from the granite, which may be clearly seen in the mountains and canyon walls. A most intricate mingling of rock types characterizes the country south of the Platte for a short distance, and eastward to Blue mountain ridge.

Western central area.—The foundation upon which the volcanic breccia of this region rests is almost entirely of fine grained, massive, reddish granite characterized by very numerous inclusions of Algonkian quartzites, fibrolitic and micaceous schists, and finely laminated gneisses of questionable origin. On the north and east of the volcanic area the granite forms very smooth park-like areas as a rule. On the south the forms are more rugged owing to numerous deep canyons. Gneissic structure appears on certain shear zones and at the head of Mac gulch foliated rocks predominate. The fine grained granite of High park and vicinity is especially full of fragments of schistose rocks. Tourmaline-bearing veins are very rarely found in this area.

Southwestern area.—The district traversed by the canyons of Currant, Cottonwood and Tallahassee creeks presents predominant gneissoid rocks derived from the shearing of fine grained red granite. There are also dark hornblendic gneisses in slight development, which appear to be derived from ancient igneous rocks. In the upper part of Currant creek there is, however, considerable massive granite. The fine grained granite type prevails in Wilson park, but the rugged mountains bounding the park are chiefly of the coarse grained porphyritic granite in which gneissoid structure is very commonly developed.

The transitions from the massive porphyritic rock to augen-gneiss are most beautifully shown in the mountain south of Twelve Mile park. The great quartzite inclusion of Wilson park forms one of the most noticeable features of this portion of the area.

Vicinity of Cripple Creek.—Cripple Creek lies on the line where the coarse granite of the Pikes peak type is cut by many arms of fine grained granite of the western area. The canyons carved by the eastern tributaries of Oil creek present these two granite types in extremely complicated association. For the most part the rock is massive or but indistinctly gneissoid, yet local shear zones expose finely laminated rock. Both granites are characterized by many inclusions of fibrolitic and micaceous quartzites. To the east of Cripple Creek, on Middle Beaver creek, the transition from granite to gneiss is most clearly shown in many exposures on and near the Colorado Springs road.

Southern district.—The plateau extending southward from Cripple Creek is generally characterized by coarse grained granite and gneissoid forms derived from it. A fine grained massive granite, however, is very prominent in the region cut by the deep canyon of East Beaver creek. In Eight Mile canyon are many beautiful exposures of gneissoid rocks, showing their relationship to the massive granite, and on the lower slopes adjacent to the sedimentary rocks finely laminated gneisses are very common. Their strike is entirely discordant with that of the sedimentary rocks resting upon them. Several large inclusions of

Algonkian quartzites are shown in the granites and gneisses of this district, the most prominent ones being in Cooper mountain, and in Eight Mile canyon at McCourt camp.

AREAS OF SEDIMENTARY ROCKS.

Southeastern area.—In the southeastern corner of the district, where the sedimentary formations of the plains are upturned at the base of the granite mountain mass, the characteristic foot-hill structure is very clearly illustrated. The outermost formation here exposed is the Dakota sandstone forming mesas sloping gently to the south but presenting a cliff front to the northwest and toward Beaver creek, which cuts through it. The gentle dip of the Dakota causes it to form mesas in the districts of the Colorado Springs, Pueblo and Canyon city sheets. The Morrison formation occurs in a narrow zone below the Dakota cliff and in the valley of Beaver creek. Between the Morrison and the base of the mountain is a broad zone underlain by the crumbling grits of the Fountain beds, which by their disintegration and ready erosion produce little park areas. The dip of these beds are 10° to 15°, except for the lower strata which acquire a dip of 30° or more, and run some distance up on the foot-hill ridges. A rather narrow band of the Harding and Manitou formations appears below the Fountain grits, and extends back on the ridges to variable distances.

To the west of Eight Mile canyon the Silurian rocks reach far up on the mountain slopes, apparently because of the protecting sheet of Fremont limestone which is here present above the Harding sandstone.

Crossing the lower part of Eight Mile canyon is an overthrust fault with a northeast-southwest trend and steep dip which passes into a fold at either end, but has produced a considerable dislocation in its central part, bringing up the crystalline rocks on the southeastern side.

Garden park bay.—Wrapping around the end of the Colorado range the sedimentary formations extend northward into an old bay the boundaries of which have varied greatly at different times. The principal element in the present structure of the sedimentary formations of this bay is a flat syncline whose axis pitches at a low angle in a southerly direction. At the mouth of the bay are seen the Colorado and Dakota rocks of the Cretaceous period, the latter forming a regular dip slope on either side of Oil creek, bounded by cliffs which are well expressed upon the map. Near the border of the map on both sides of this syncline the Dakota assumes a steeper dip, forming characteristic hogback ridges, one extending southward to Canyon city, and the other curving eastward to a connection with the mesa of the southeast corner. Below the Dakota the Morrison formation extends a long distance into the old bay, with remnants of the Dakota here and there upon it. In this formation near Oil creek are the famous Dinosaur beds from which great numbers of type specimens have been obtained. Oil has been found in small quantity in the Morrison beds not far below the Dakota, on the eastern side of Oil creek.

The Fountain grits form the floor of Garden park proper and extend northward until cut off by a transverse fault. The northern part of the Garden park bay contains three Silurian formations exposed in southerly dipping mesas, cut by canyons affording excellent exposures. In Red ridge, at the extreme northern limit of the bay, a remnant of Fountain beds rests nearly horizontally upon the edges of the Silurian formations. The preservation of the Fountain beds is due to a rhyolite sheet above them.

The present limitations of the sedimentary formations of Garden park bay are chiefly determined by a complicated system of faults. These have lowered the bay area with respect to the granite mountains on either side. They are situated principally at the foot of steep monoclinal folds on either side of the syncline. Variations in strike of the steeper inclined beds on the mountain sides have brought them against the fault in several places in such a way that the formations have been successively sheared off in the manner represented upon the map. The principal faults trend nearly north and south, but several smaller transverse faults have greatly complicated the structure. The great fault east of Helena canyon is most clearly marked. Its throw near Wilson creek amounts to nearly 1,000 feet, but greatly diminishes southward to the vicinity of Millsap creek, where it passes into a fold. To the north of Wilson creek within the semicircular curve in the course of this fault there has been a slight overthrust movement of the granite upon the sedimentary beds. Profile sections DD and EE of the structure section sheet cross Garden park bay.

Twelve Mile park.—In Twelve Mile park and extending over the little divide into West Eight Mile park is an isolated area of Mesozoic strata in a synclinal basin. The Morrison, Dakota, Colorado and Montana formations are present, but on the southwestern side the Colorado shales apparently overlap the lower formations along a shore line. Near Bumback Springs a small remnant of Manitou limestone is found dipping beneath the Morrison beds. All this area was once directly connected with the Mesozoic of Garden park bay over the low divide, and also with the strata now found about Parkdale in the Arkansas valley to the south.

Remnants upon the plateau.—Near the southern end of the Colorado range several small remnants of Silurian limestone have been found in nearly horizontal position, at elevations up to something more than 9,000 feet. The highest and most northerly of these remnants is on the ridge east of Lower Beaver park. Another appears one mile southeast of Nipple mountain, while several smaller ones occur on the southern spurs of Cooper mountain. The largest patch appears on an unnamed mountain east of Eight Mile canyon.

In the last named remnant the Harding sandstone is present with a very thin layer of Manitou limestone below it, and in all other cases it is usually the cherty lower layer of the Manitou which is preserved. Similar remnants found beneath the Morrison beds near Bumback Springs and on the south side of Wilson park, show that the Silurian ocean of the Manitou and perhaps of other epochs covered considerable territory on either side of Garden Park bay. These remnants have been isolated by erosion in the arch of the monoclinal fold, probably during the interval between the Millsap and Fountain epochs of the Carboniferous period.

West of Oil creek a patch of Dakota sandstone occurs on the south side of Wilson park; two patches of Morrison and Dakota occur on West Wilson creek southeast of Cap rock; in and near High park are several small remnants of the Morrison beds; and in The Basin, below the volcanic breccia, is a well characterized exposure of Dakota and Colorado (Cretaceous) strata. All of these remnants occur either in park depressions or where they have been protected by overlying volcanic rocks. They seem to represent deposits in hollows of a sea whose floor was gradually sinking.

Manitou park basin.—In the northeastern corner of the district, near the head of Fountain creek, occurs the southern end of the Manitou park basin of Silurian and Carboniferous rocks. The basin structure now seen is apparently due entirely to folding, and the strata are supposed to have been connected with the main areas to the east. On the eastern edge of this basin the Manitou limestone appears as a narrow band in vertical position. Above it the Fountain grits possess a greatly diminished dip toward the west and on the eastern line abut against the granite. Whether this western contact represents a fault or an ancient shore line is not definitely known. The basin ends to the south on account of the northerly pitch of the synclinal axis. The structure is shown in section AA of the structure section sheet.

Eocene and Neocene lake basins.—The largest of the post-Cretaceous lake basins, that about Florrissant, has been quite fully described in discussing the character of the sediments. It does not appear to have been at any time much larger than is indicated by the strata now preserved. The Alnwick lake in the valley of Oil creek appears also to have been limited by topography very much like that of the present day. The lake of High park, however, had an extension to the southeast as shown by the remnant of its lowest conglomerate found upon the rhyolite sheet capping Red ridge. There is no evidence concerning its former limitation in this direction. Apparently this lake must have had a considerable body of water, for the chief constituent of its conglomerate is the extremely hard Algonkian quartzite which occurs only in small perfectly rounded pebbles, affording evidence of a great amount of attrition. There is at present a difference of 500 feet in elevation between the floor of High park and the summit of Red ridge.

AREAS OF VOLCANIC ROCKS.

Western central area.—The largest area of volcanic rocks in the district represents the eastern extremity of a volcanic formation which occupies the greater part of the elevated country between South park and the Arkansas river. The principal formation in this volcanic complex is a dark, basic breccia and agglomerate with numerous intercalated basalt sheets and dikes. This agglomerate accumulated on an irregular floor of granite and gneiss, as proved by the local projection of granite through it and the occurrence of the agglomerate in valleys and hollows. The basic breccia forms mountains and mesas, the largest masses lying, however, west of the area mapped.

North of Four Mile creek are several mountains composed of the agglomerate with capping sheets of andesite. To the south the agglomerate forms the main part of Wicher mountain, and in its further extension produces the large dissected mesas on either side of West Wilson creek. The large intercalated andesite sheet has been an important element in the preservation of these mesas.

Massive andesite and trachyte also form hills and mountains within this general area. These rocks are more recent than the earliest portions of the great breccia formation and are distinctly older than the upper part of the fragmental deposits. Dikes of these rocks penetrate the lower part of the breccia in great abundance. Rhyolite occurs in small masses associated with the other volcanics, apparently in remnants of an extensive but thin surface flow. There is a local center of andesitic eruption on the south side of Four Mile creek opposite Truro. The rocks of this large volcanic region are as a rule very fresh.

High park.—Near the center of the High park depression are some prominent hills composed of a rather fine grained tuff and agglomerate chiefly of andesitic material. Southward from these hills the even floor of the park is covered by a thin rhyolite flow, upon which the High Park lake beds were deposited. The relative age of the volcanic rocks here exposed was not positively determined. But the absence of andesitic debris in the sediments of the High park lake seems to show that the andesitic tuffs are younger than the rhyolite. In the hill on the eastern side of the park the lake beds are found between flows of rhyolite and phonolite.

The Bare hills.—Southward from High park is a group of bare, grassy hills upon the site of a vent of andesitic eruption. The earliest outburst at this point produced a fine grained, light colored tuff full of fragments of granite. Penetrating this tuff are several necks and dikes of dense hornblende-mica-andesite. The surface masses erupted through these channels built up the higher portions of the hills resting upon the tuff or upon the outlying granite.

Southwestern area.—In the extreme southwestern corner of the district is a narrow mesa which is capped by several thin sheets of olivine-bearing andesite which rest upon rhyolitic breccia and tuff, beneath which on the northern side are remnants of a dark basic breccia seemingly equivalent with that to the north. On the northern side of Tallahassee creek rhyolite and basic breccia seem to alternate. Both of these isolated patches belong to the great western volcanic district the margins of which approach very near the border of the map.

Cripple Creek district.—The group of hills containing the mines of the Cripple Creek region are chiefly made up of a much decomposed andesitic tuff, breccia, and agglomerate formation, with small bodies of massive andesite, and penetrated by numerous dikes of phonolite. Detailed descriptions of the central portion of this region accompany the special map of this folio. Beyond the borders of the special map there are, however, many phonolite masses which are distinctly grouped about this center, and are to be considered as belonging to it.

The outlying phonolite masses range from a point on the slopes of Pikes peak itself, seven miles northeast of Bull mountain, to Nipple mountain on the south and High park on the west. Nearly all of the larger bodies seem to be surface masses from sources immediately below them. East of Little Pisgah peak there is a large irregular neck of phonolite, cutting the granite in the rugged cliffs facing Wilson creek. A great many dikes of phonolite are found in granite on all sides of the volcanic center. Traces of rhyolitic tuff and breccia found at a few points indicate the almost complete destruction of a formation of this character which may have been quite extensive.

Scattered remnants of rhyolite.—The geologic map shows a large number of very small patches of rhyolite, most numerous in the vicinity of the Florissant lake, but also noticed as far south as the eastern ridges of the Bare hills. The rock of all of these patches indicates a finely banded surface flow of no great thickness. The rock is very uniform in appearance throughout the region, but the remnants found occur at many different elevations entirely independent of present topography. In how far the differences of level observed have been produced by faults undetected in the granite it is impossible to say, but the fact that the rhyolite capping of Red ridge bears upon it a conglomerate apparently identical with the High park conglomerate, indicates a dislocation between these points of nearly 500 feet, and it is quite probable that many other differences in elevation of rhyolite remnants are due to the same cause.

STRUCTURAL DEVELOPMENT OF THE REGION.

No approximately complete sketch of the geological history of this region can as yet be written, owing to the reconnoissance character of the observations thus far made, and the obscurity of the evidence concerning some of the most important geological periods. The data that have been presented, however, throw new light upon the history of certain periods, and a summary review of the succession of events as thus indicated will be given.

Age of the granites and gneisses.—The granites and gneisses of the Rocky mountains have always been considered to be a part of the Archean, the oldest known complex of rocks, whether deemed to be plutonic eruptives or of metamorphic origin. But a remarkable feature of the area of the Pikes peak sheet, now observed for the first time, is the occurrence in the main granitic masses of an enormous number of included fragments of quartzite and of schists derived from them. The purer quartzites are plainly indurated sandstones, necessarily older than the granites which include them. From considerations presented elsewhere these ancient sediments have been referred to the Algonkian period. The granites cutting these strata are then either of Algonkian age or of early Cambrian, and it is deemed most in harmony with the other facts in the case to refer the granite eruptions to the later Algonkian period. With such an age assigned to the granites the dynamic movement which produced gneisses out of them may well be considered indentical with that which preceded the Cambrian. It is known that the gneissic structure in question was produced before the period of the upper Cambrian, during which time sediments were deposited upon these gneisses in the Colorado range.

Pre-Paleozoic land areas.—The fragments of quartzite, schist and gneiss included in the granite must be regarded as representing the oldest known rocks of this portion of the Colorado range. But it is impossible from present knowledge even approximately to define the continental areas of the period of sedimentation, or the extent of the deposits. The enormous granite masses which broke into and through these oldest formations doubtless formed extensive land areas. but it seems probable that the great dynamic movements which transformed so large a part of these massive granites into banded gneisses were the ones which gave outline to the continents about which the upper Cambrian and Silurian strata were deposited. Much further investigation is necessary to determine how large a part of the gneisses in other portions of the Rocky mountains has been formed from granites contemporary in origin with those of the Pikes peak district.

The main structural axis of this portion of the Rocky mountains has a trend north-northwest and it is parallel to this general direction that the banded structure of the gneisses has been developed. There are many minor deviations from this rule, but the broad correspondence in structures is nevertheless plain. From the upper

Cambrian to the Eocene it seems probable that the oceanic shore line along the eastern base of the Colorado range remained very near the present line of contact of the sedimentary formations, except in certain epochs.

Early Paleozoic movements.—The overlapping of later formations conceals the older Paleozoic deposits except where they have been exposed in a few isolated localities by some special structural disturbance and subsequent erosion. It is however to be assumed that all of the known formations had at least a considerable extension along the eastern base of the Colorado range. The exposures in Manitou park and on the plateau to the south of Pikes peak show that the late Cambrian and early Silurian oceans covered a part of what is now mountainous territory.

Orographic movements of probably minor importance during lower Silurian times are proved by unconformities between the Silurian deposits of Garden park bay and vicinity. The chief of these appears to have been between the Manitou and Harding periods; the Harding sandstone in certain places resting upon granite through erosion of the earlier strata.

Between the lower Silurian (Ordovician) and lower Carboniferous periods there must have been a time of non-deposition and erosion, some clear evidence of which is found in an undoubted unconformity between the Millsap (Carboniferous) limestone and the Fremont (Silurian) limestone.

Carboniferous movements.—The extent and character of the deposits laid down in this region in the lower Carboniferous period are practically unknown. The thin, locally preserved remnants of the Millsap limestone are all that remain of what may have been a thick formation. Of the Fountain beds there was, however, uplift, folding and erosion, continuing through an interval of unknown duration. If the Fountain grits be assigned to the upper Carboniferous the preceding interval embraced very probably the middle Carboniferous, and was correspondingly longer if the grits belong to any later period. There is no evidence to indicate that the known Fountain beds conceal by overlapping any earlier strata of the same general period of sedimentation.

Movement preceding the Morrison epoch.—The presence of Morrison and Cretaceous remnants upon granite and gneiss in the western part of the Pikes peak district proves that prior to the Morrison epoch there began a great subsidence which continued until the latter part of the Cretaceous, admitting oceanic waters to the west of the Colorado range and apparently establishing a connection with South park. The extent and duration of the periods of elevation and erosion which preceded this subsidence are not indicated in the region of the map, but if the Fountain grits were deposited during the later Carboniferous, there is no record here of the passage of time to the middle of the succeeding period, which is elsewhere represented by thick sediments. These have been assigned by other geologists to the Permo-Carboniferous and Triassic during which thick sediments accumulated elsewhere in the Rocky mountain region. If deposits were formed during these periods in this region they were eroded before the subsidence preceding the Morrison.

The district of the Pikes peak sheet presents no evidence concerning changes during the long Cretaceous period, except those which are common to the general Rocky mountain region.

Post-Cretaceous movement.—The upturning of the sedimentary formations in a narrow zone along the foot hills of both the Colorado and Wet mountain ranges has probably been a progressive movement, interrupted at intervals by disturbances whose characteristics are imperfectly recorded in the unconformities described. But from the evidence in the Denver region it is known that a movement of special intensity took place at the end of the coal-bearing Laramie (Cretaceous) epoch and another followed some time during a subsequent period, by which the post-Laramie (Cretaceous) formations were also steeply upturned, corresponding in position to the older formations. From the structure found in Huerfano park at the south end of the Wet mountains it is known that a further movement of this character took place after the Bridger (Eocene) epoch. But as no strata later than the Montana (Cretaceous) formations are exposed near the southern end of the Colorado range it is impossible definitely to connect the last important disturbances of the Pikes peak district with any of these great orographic movements. Thus the upturning in which the Cretaceous strata have taken part may correspond to the post-Laramie or to some distinctly later movement. The faults of Garden park bay are probably still later than the folding.

PLEISTOCENE GEOLOGY.

Glaciation.—Evidence that local glaciers once existed on the upper slopes of Pikes peak is found in moraines, more or less rearranged, occurring especially on the eastern and southern slopes of the peak at about 10,000 feet elevation. The most noteworthy morainal accumulation of the region embraced by the map is that east of Trachyte mountain. The branch of Beaver creek which rises in the amphitheatre south of the summit of Pikes peak was evidently occupied by a glacier, which deposited a great mass of material at the mouth of its canyon. This has apparently been greatly modified by rearrangement and disintegration of the granite boulders. Probably much evidence of glaciation has been destroyed by the surface decay of the granite.

In the vicinity of Divide and Summit several square miles of smooth grassy country are underlain by a superficial formation which is apparently glacial drift, consisting of small rounded bowlders and gravel. Phonolite and various other eruptive rocks of the region are represented among these bowlders. Very similar material also appears on the plateau-like crest of the Colorado range, in the extreme northeastern corner of the mapped area. The origin of this material and its distribution beyond the map borders were not ascertained.

Disintegration of the Pikes peak granite.—A marked feature of the coarse grained Pikes peak granite is the readiness with which it disintegrates under the action of atmospheric agencies. Many slopes of the peak proper, and large areas of the adjacent plateau are covered by coarse angular gravel, resulting from the disintegration of the granite in place. This gives rise to gentle and rounded forms except where erosion has had opportunity to remove the loose material.

Erosion.—The topography of the southern portion of the district has been greatly modified by erosion during recent epochs. Thus the southern end of the Colorado range has had its plateau character almost obliterated by the erosion of many deep canyons by the tributaries of Oil, Eight Mile and Beaver creeks. The plateau country west of Pikes peak has on the other hand suffered comparatively little erosion since the time of the post-Cretaceous lake basins and the filling of the valleys with volcanic material.

The southwestern portion of the district and the region traversed by the Arkansas, a short distance further south, exhibit many remarkable peculiarities in the courses of deep canyons in relation to the physical character of the rocks in which they have been eroded. The soft sedimentary rocks of the Cretaceous bay do not seem to have determined the courses of any of the larger streams in this region.

LITERATURE.

The most important publications on the geology of the Pikes peak district or its vicinity are given in the following list. References to this list are indicated by figures in brackets in the preceding text.

1. Geological and Geographical Atlas of Colorado and portions of adjacent territory, by F. V. Hayden, geologist in charge, U. S. Geol. and Geog. Surveys of the Territories. Department of the Interior, Washington, 1877. The Pikes peak district is included in Sheet XIII.

2. *A. C. Peale.* Annual Report of the Geol. and Geog. Surveys of the Territories for 1873. The region about Manitou Springs, Manitou park, and the northern portion of the Pikes peak district are described on pages 193 to 212.

3. *F.N.Endlich.* Ibid. A description of the southern part of the Pikes peak district is contained on pages 305 to 322.

4. *F. V. Hayden.* Annual Report of the U. S. Geol. and Geog. Survey of the Territories for 1874. A general description of the sedimentary formations recognized along the foot hills, with a map of the vicinity of Manitou Springs and references to local geology, will be found on pages 40 to 46.

5. *Samuel H. Scudder.* The Tertiary Lake basin at Florrissant, Colorado, etc. Bulletin U. S. Geol. and Geog. Survey of the Territories, Vol. VI, No. 2, pp, 279–300, 1881. Gives a general sketch of the Florissant basin, with lithological descriptions of the tuffs and a statement concerning the fossil fauna and flora.

6. *Whitman Cross* and *W. F. Hillebrand.* Contributions to the Mineralogy of the Rocky Mountains. Bulletin U. S. Geological Survey, No. 20, 1885. Minerals from the neighborhood of Pikes peak, pp. 40–74. Describes the cryolite of St. Peters dome and its alteration products, and also topaz, phenacite, zircon, etc. from veins in granite.

7. *Samuel H. Scudder.* Tertiary Insects of North America, U. S. Geol. and Geog. Survey of the Territories. Monograph XIII, 1890. The greater part of the insects described came from the Florissant lake beds, and there is a description of the locality similar to that of 5.

8. *C. D. Walcott.* Preliminary notes on the discovery of a vertebrate fauna in Silurian (Ordovician) strata. Bulletin Geological Society of America. Vol. 3, pp. 153–172, 1892. This paper contains a description of the ichthyic fauna of the Harding sandstone, with preliminary lists of invertebrates in the Harding, Fremont, and Millsap formations, and notes on the geology of the region between Canyon city and Garden park.

9. *Whitman Cross.* Intrusive sandstone dikes in granite. Bulletin Geological Society of America. Vol. 5, 1894, pp. 225–230.

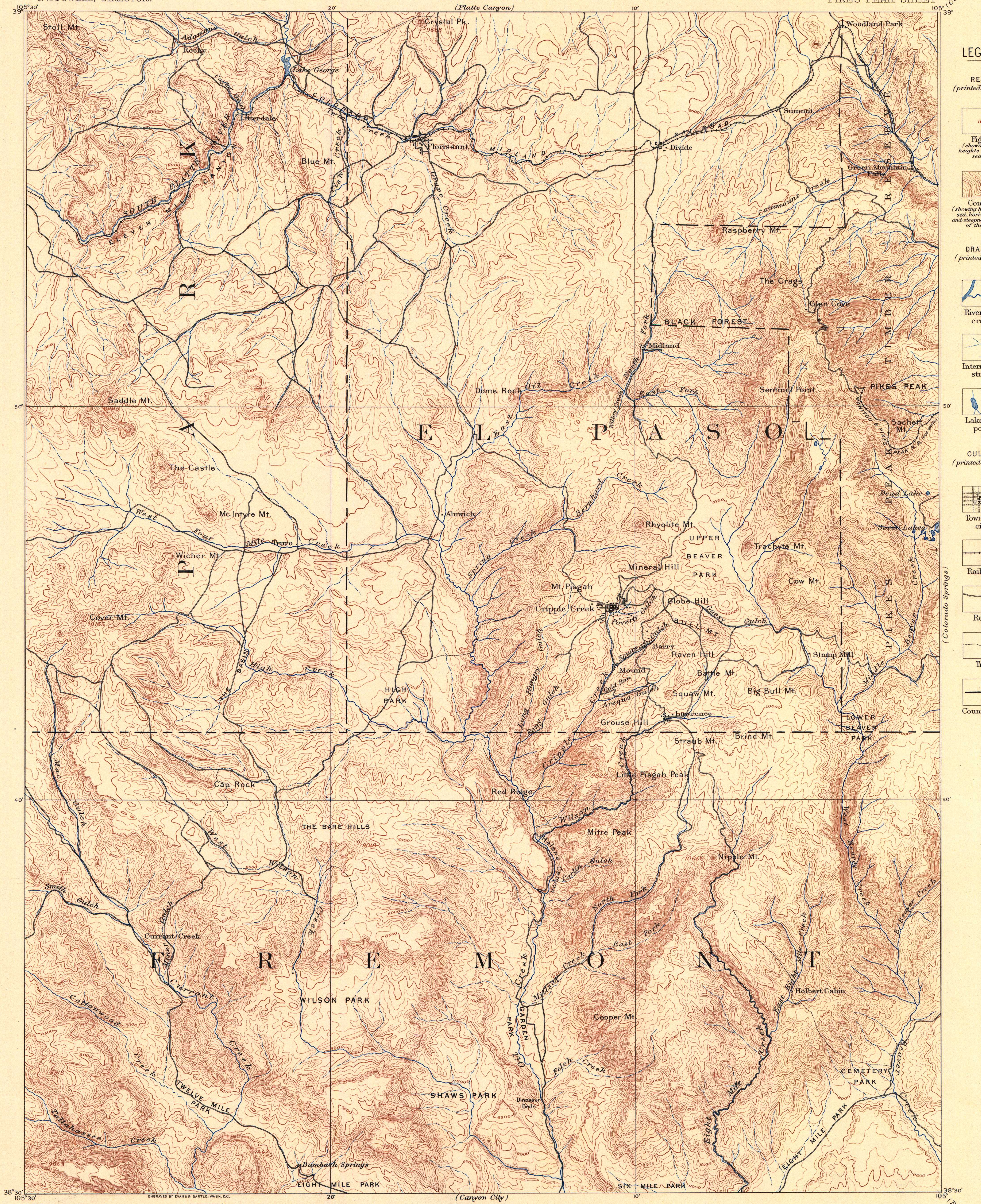
WHITMAN CROSS,
Geologist.

June, 1894.

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

TOPOGRAPHY

COLORADO
PIKES PEAK SHEET



LEGEND

RELIEF
(printed in brown.)

- 10165 — 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 and creeks
- Intermittent streams
- Lakes and ponds

CULTURE
(printed in black.)

- Towns and cities
- Railroads
- Roads
- Trails
- County lines

A. H. Thompson, Geographer.
E. M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by W. S. Post and R. A. Farmer.
Surveyed in 1892-93.

Scale $\frac{1}{125,000}$

1 0 1 2 3 4 5 Miles

Contour Interval 100 feet

Edition of Mar. 1894.

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

AREAL GEOLOGY

COLORADO
PIKES PEAK SHEET

LEGEND

SEDIMENTARY

Symbol	Formation	Description	Age
Nlw	Alnwick lakebeds	(Sandstone and conglomerate)	NEOCENE
Nhp	High Park lakebeds	(Sandstone and conglomerate)	NEOCENE
Ef	Florissant lakebeds	(Volcanic tuff and paper shale)	EOCENE
Km	Montana formation	(Here probably includes only the Pierre shale)	CRETACEOUS
Kc	Colorado formation	(Niobrara limestone and shale, Benton limestone and shale)	CRETACEOUS
Kd	Dakota formation	(Sandstone, conglomerate and fire clay)	CRETACEOUS
Jm	Morrison formation	(Marl, sandstone and a thin limestone at base, locally gypsiferous)	JURATRIAS
Cf	Fountain formation	(Arkose sandstone, grit and conglomerate: a part of the Red beds: possibly Juratriassic)	CARBONIFEROUS
Cm	Millsap limestone	(Dolomitic, thinly bedded variegated limestone, cherty in the upper part)	CARBONIFEROUS
Sf	Fremont limestone	(Dolomitic, grey or pink limestone, of uneven texture and cavernous, forming very rough weathered faces)	SILURIAN
Sh	Harding sandstone	(White and variegated layers alternating; fine grained, saccharoidal)	SILURIAN
Sm	Manitou limestone	(Dolomitic; includes at the base cherty limestone and quartzite of Upper Cambrian age)	SILURIAN
A		Pure quartzites passing into quartzitic, micaceous and fibrolitic schists in detached masses included in granite and gneiss	ALGONKIAN

IGNEOUS

Symbol	Rock	Description
ph	Phonolite	(In dikes, necks and surface masses)
rh	Rhyolite	(Mainly in massive flows, locally breccia and tuff)
tr	Trachyte	(Massive or brecciated)
an	Andesite	(Exhibiting varying development of augite, hornblende and biotite)
bb	Basic breccia, agglomerate and tuff	(Mainly basaltic, partly andesitic, with thin local flows and narrow dikes of basalt)
anb	Andesitic breccia and tuff	(Carries the gold deposits of Cripple Creek district, where it is much decomposed)
Agr	Granite and gneiss	(Includes several types of granite and the gneisses derived from them by shearing stress; possibly also gneisses of Archean age)
S	Sandstone dikes in granite	(Mechanically intruded)

A.H. Thompson, Geographer.
E.M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by W.S. Post and R.A. Farmer.
Surveyed in 1892-93.

Farmer
Post

Scale $\frac{1}{125,000}$
1 0 1 2 3 4 5 Miles
Contour Interval 100 feet
Edition of Mar. 1894.

Chas. D. Walcott, Geologist in charge
Geology by Whitman Cross.
E.B. Mathews, Geological Assistant
Surveyed in 1893.

U.S. GEOLOGICAL SURVEY
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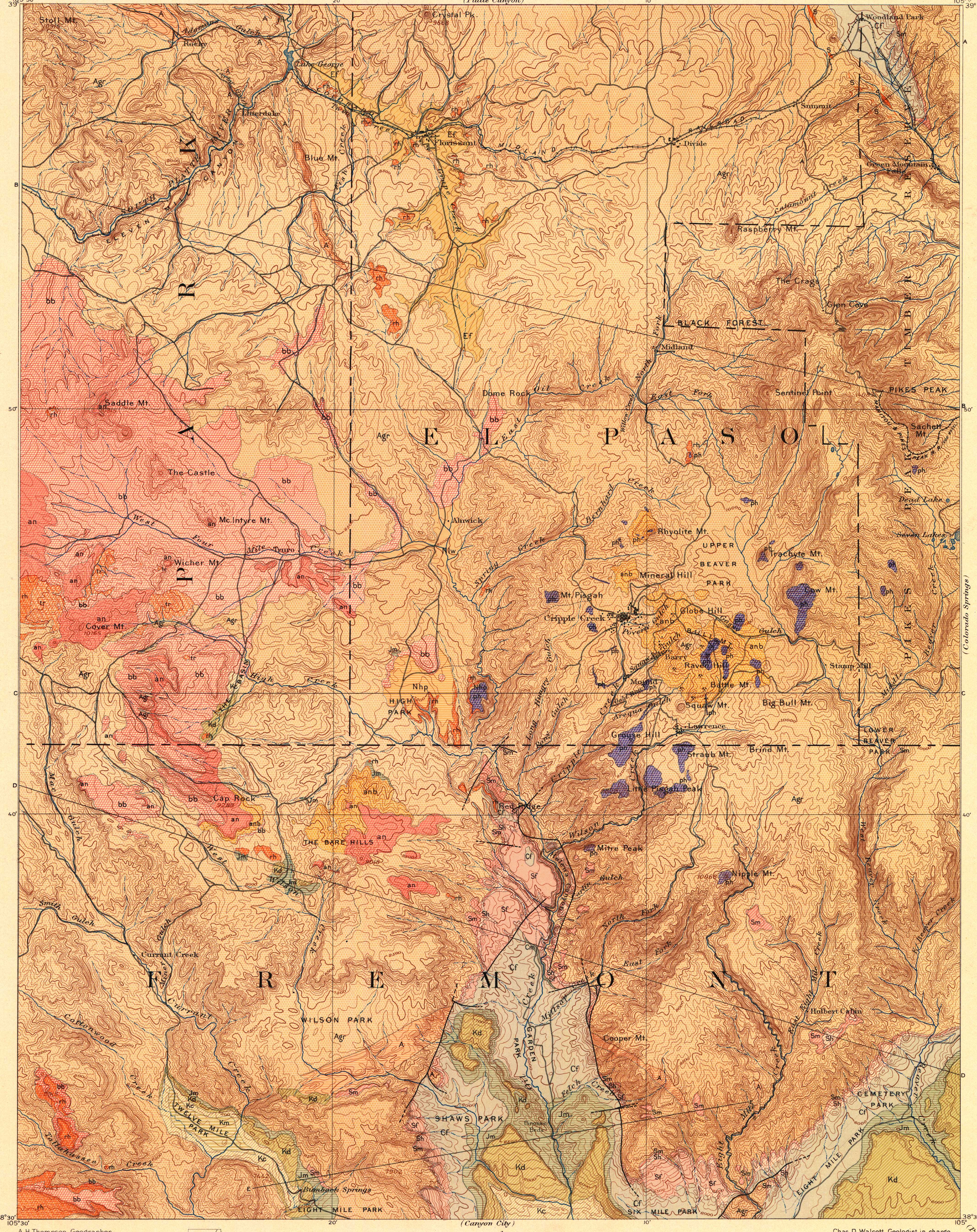
ECONOMIC GEOLOGY

COLORADO
PIKES PEAK SHEET

(Platte Canyon)

(Castle Rock)



(Canyon City)

A.H. Thompson, Geographer.
E.M. Douglas, Topographer in charge.
Triangulation by Hayden Survey.
Topography by W.S. Post and R.A. Farmer.
Surveyed in 1892-93.

Farmer
Post

Scale $\frac{1}{125,000}$

1 0 1 2 3 4 5 Miles

Contour Interval 100 feet

Edition of Mar. 1894.

Chas. D. Walcott, Geologist in charge
Geology by Whitman Cross.
E.B. Mathews, Geological Assistant
Surveyed in 1893.

(Pueblo)

LEGEND

SEDIMENTARY

Symbol	Formation	Description	Age
Nlw	Alnwick lakebeds	(Sandstone and conglomerate)	NEOCENE
Nhp	High Park lakebeds	(Sandstone and conglomerate)	
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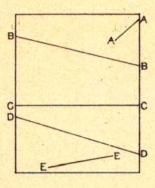
Agr	Granite and gneiss	(Includes several types of granite and the gneisses derived from them by shearing stress, possibly also gneisses of Archean age)

Symbol	Description
S	Sandstone dikes in granite (Mechanically intruded)
⚒	Mines (Producing gold with a little silver)



U. S. GEOLOGICAL SURVEY
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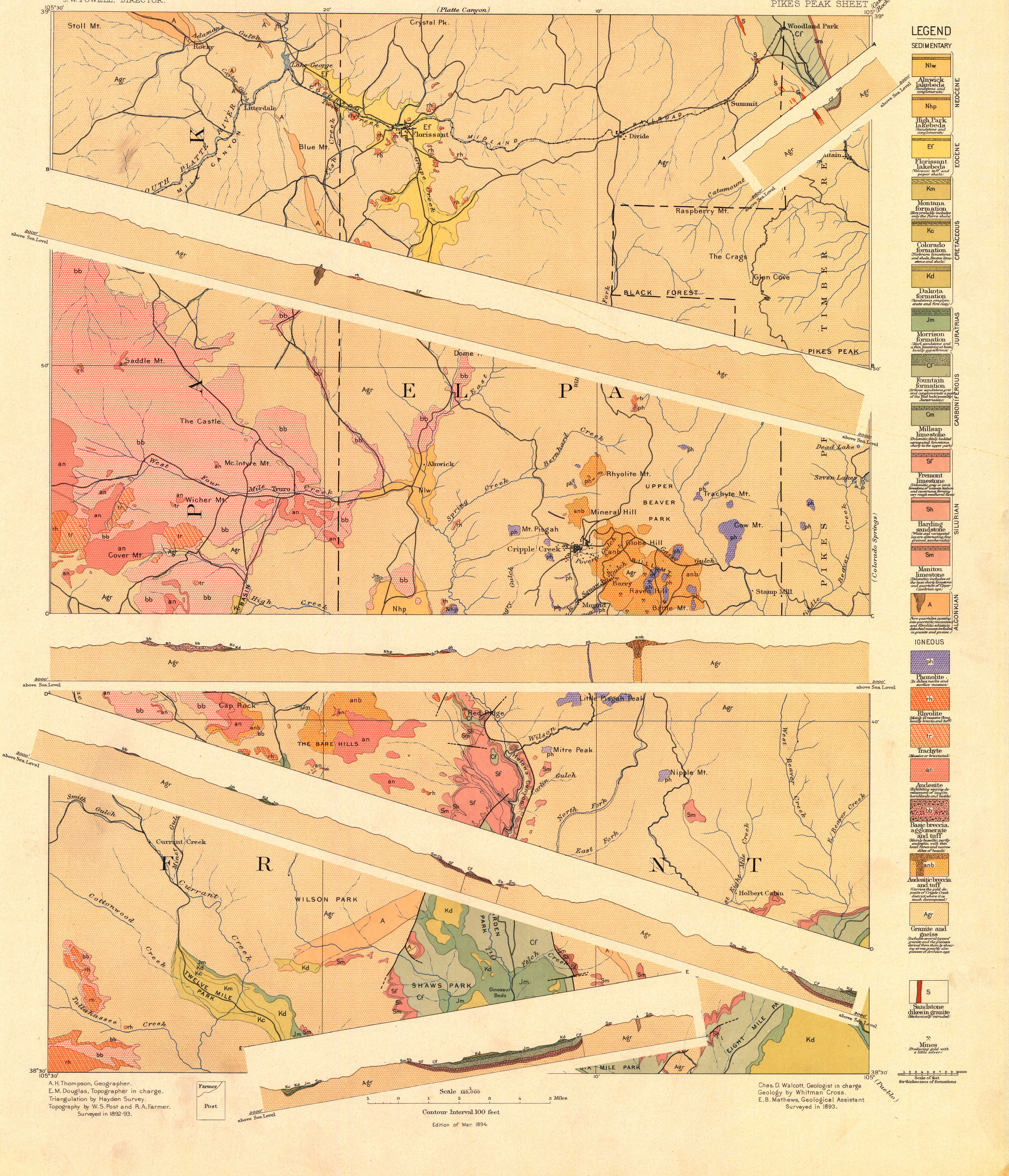
STRUCTURE SECTIONS

COLORADO
PIKES PEAK SHEET



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DESCRIPTION OF THE CRIPPLE CREEK SPECIAL MAP.

GENERAL GEOLOGY.

The field work upon the Cripple Creek special map was done in September, October, and November, 1894, after the publication of the Pikes Peak sheet. As the scale of the special map is larger the geological details represented upon it are more complex in character, differing greatly from the simple outlines of the atlas sheet. The outline of the central volcanic area is practically unchanged, but the formation within it has been subdivided and several rock varieties have been distinguished. Outside the volcanic center the schist inclusions in granite have been indicated, and also a few other formations not shown upon the atlas sheet. The area covered by the special map is about 38 square miles.

INTRODUCTORY SKETCH.

The central portion of the area mapped is a typical volcanic complex. It consists of predominant fragmental materials — tuff and breccia — with numerous dikes and irregular intrusive bodies of massive rocks. This part is naturally the most complicated and interesting geologically, and it is also of the greatest economic importance, because the gold deposits are there most numerous.

Surrounding this central area is granite, the principal rock, penetrated by dikes of certain of the volcanic rocks. Remnants of tuff and breccia also occur, and there are a few subordinate formations which are not directly connected in origin with the volcanic center. The High Park lake-beds and the associated rhyolite of Grouse Mountain are the principal of these formations.

The study of the district has led to the conclusion that there was once a true volcano at this center of eruption. It was probably small in comparison with the one west of it, but it exhibited a very complete cycle of phenomena characteristic of volcanic vents. Owing to the extreme decomposition suffered by many of the rocks under the action of gases and thermal waters many features are at first difficult of recognition.

ROCK FORMATIONS.

Granite and gneiss.—The coarse-grained granite of the Pikes Peak type prevails in the district, except to the west of Cripple Creek, where a finer-grained type occurs. Fine red granite dikes abound throughout the granite area, and coarse pegmatite dikes are occasionally found. Gneissic structure is locally developed in the granites, but neither this structural change nor the distribution of the granitic varieties could be shown on the map, owing to the limited time available for the investigation.

Schist.—The numerous small areas designated schist are not so clearly metamorphosed Algonkian strata as are many in the adjoining district to the west, but they are plainly included masses in the granite, and hence to be considered older than that rock. Most of these schistose rocks are silvery muscovite-quartz-schists, with fibrolite in many cases. Some are doubtless altered gneisses, while others are metamorphosed Algonkian sedimentary rocks. Those near the volcanic area are much kaolinized. Small granitic veins or dikes penetrate the schist.

Diabase.—Several diabase dikes in granite are shown upon the map. They are all small and short, and are numerous only near Cripple Creek town and in Brind Mountain. These are probably of Algonkian age, belonging to a series of wide distribution in the Front Range, and not with the rocks of the volcano. Augite is commonly changed to uralitic hornblende in these dikes.

Andesite.—The andesites represented upon the map, though not very different in character, are of two principal epochs of eruption. The more important type is an augite-hornblende-andesite with some mica. It is probably the earliest massive rock of the volcano, and the small areas of Battle and Big Bull mountains are regarded as representing a large body which has been in great degree destroyed by explosive outbursts or covered by the tuff and breccia of the eruption. This andesite is characterized by its large prismatic crystals of apatite, which are often larger than any other constituent of the rock.

The second andesitic variety occurs in dikes cutting the breccia, especially in Anaconda Ridge and Poverty Gulch. The rock is an augite-andesite with some hornblende and mica, and has a denser groundmass than the earlier type. An andesite rich in mica occurs in dikes in Battle Mountain, but is not represented on the map.

Phonolite.—The specially characteristic rock of the region is phonolite. It occurs in numerous narrow dikes, both within and without the main volcanic area, and is the only one of the volcanic types having such a distribution. It also occurs in several isolated bodies capping granite hills or mountains for some miles on all sides of the center, as in Trachyte, Big Bull, Cow, and Nipple mountains. These masses are thought to be remnants of large inclined dikes in granite, similar to those shown upon the map in the territory just west of the volcanic center. This origin is further suggested by the phonolite bodies of Grouse and Straub mountains, which are clearly lateral intrusions into the High Park lake-beds, near the granite surface. No surface flows of phonolite are now identifiable.

Phonolite was a product of several epochs of eruption, for a part of the breccia contains phonolite fragments, and this breccia is cut by phonolite dikes. The dikes are also of several epochs.

The phonolite consists of alkali feldspars, nepheline, sodalite, nosean, and pyroxene which is in great part ægirine. Accessory minerals are sometimes present, the most notable ones being lovenite and a peculiar blue amphibole. The smaller dikes are dense, of greenish-gray color, and have a pronounced fissile or schistose structure, due to the arrangement of the predominant scales or microlites of feldspar parallel to the dike walls. A few glassy sanidine tablets give a more or less distinct porphyritic structure to many masses. The phonolite of Grouse Mountain and of some smaller bodies is porphyritic through the unusual development of nepheline in numerous macroscopic, reddish crystals. Analcite occurs in drusy cavities in certain places.

Trachytic phonolite.—The large mass of Bull Hill, and some smaller ones in or near Bull Cliff, belong to a rock closely allied to the ordinary phonolite but deserving to be distinguished from it by the smaller amount of nepheline it contains and by its structure. There are many stout feldspar crystals in this rock, and it is not laminated. In its prevalent decomposed condition it bears little resemblance to the normal phonolite, though the fresh rocks of the two types are nearly identical in chemical composition. Sodalite and nosean are as abundant as in the other type.

Nepheline-syenite.—A single mass of this rock occurs at the south base of Bull Hill. It possesses nearly the same chemical and mineralogical composition as the phonolite, but has less nepheline, sodalite, and nosean, and a primary green hornblende is associated with the augite. The rock is pearl-gray in color, with a fine-grained granular structure, excepting on the periphery, where it becomes porphyritic. The presence of this granular equivalent of phonolite in the heart of the volcanic district suggests more definitely than anything else the site of the actual vent of the volcano.

Syenite-porphyry.—On the southeast shoulder of Gold Hill is a mass of augitic syenite-porphyry, with many small feldspar and augite crystals in a very coarse-grained feldspathic groundmass. Little of the lime-soda or plagioclase feldspar series is present. Nepheline, sodalite, and nosean are wanting, but the strongly predominant alkali feldspars ally this rock with the phonolite series. Hornblende and mica are subordinate constituents.

Basic dike rocks.—The last eruption of the district produced a number of narrow dikes of dark basic rocks. These are usually very much decomposed, but from the few fresh occurrences it is plain that there are two distinct rock types among these dikes, one a nepheline-basalt, the other a normal feldspar-basalt. The latter type is shown in fresh condition in the Wilson mine at Altman, and near the Dolly Varden mine in Squaw Gulch. The former occurs in numerous dikes in Battle Mountain and Raven Hill, being shown in nearly fresh condition in the Elkton-Raven dike, and in the Black Diamond mine on Battle Mountain. The Moose, Ben Harrison, and Anna Lee dikes are of nepheline-basalt, very much decomposed, and locally impregnated with ore. Many other short dikes of Bull and Raven hills belong to one or the other of these basaltic types.

In their decomposed state these dike rocks are usually very soft, greenish in color, and often show a straw-yellow mixture of decomposition products in place of the augite prisms of the original basalt. Only a few of the best exposed nepheline-basalt dikes are represented upon the map.

Tuff and breccia.—The fragmental rocks of the central volcanic area, which are cut by all of the massive rocks described except the earliest andesite, consist of small fragments of andesite, phonolite, and granite. The predominant constituent is andesite, with phonolite locally abundant, and granite very subordinate, often confined to microscopic grains. In texture these rocks vary from fine, even-grained tuffs, composed of sand or gravel particles, to a breccia made up of small angular fragments, few over 1 inch in diameter. Very large fragments do not occur. The most abundant modification contains a few comparatively large fragments in a gravelly matrix, a form which may be called tuff-breccia.

The greater part of the tuff and breccia is without distinct bedded structure, but occasionally a bedding is visible. Owing to the extensive decomposition to which the rocks of the central area have been subjected the bleached and indurated tuffs are in many places distinguishable from massive rocks only by the closest scrutiny. Tuffs retaining in some degree their original dark colors and loose texture are found on the slopes of Bull Cliff and Battle and Big Bull mountains, especially near the isolated patches of massive andesite, and in these places the fragments of the breccia can be seen to be identical in character with the massive rock near by.

Granite occurs in the tuff-breccia most abundantly near the boundary line. Phonolite is prominent in the breccia of Anaconda Ridge, Raven Hill, and in the space between Battle Mountain and Bull Cliff.

Rhyolite.—In Grouse Mountain are isolated patches of a banded, pinkish or grayish rhyolite, associated with the High Park beds. This rhyolite contains crystals of sanidine, quartz, and biotite, in a dense groundmass which is some-times microspherulitic, though usually crypto-crystalline with more or less pronounced fluidal structure. The rock is like that represented on the Pikes Peak sheet as widely scattered over the adjoining country north and west of Grouse Mountain, and there is no reason to believe that this rhyolite was a product of the Cripple Creek volcano.

High Park lake-beds.—In Grouse and Straub mountains is a rudely bedded grit or coarse sandstone composed of granite gravel with some worn pebbles of granitic and schistose rocks and a smaller number of pebbles of hard, bluish quartzite, derived from fragments of Algonkian quartzite included in granite, described in the text of the Pikes Peak sheet. The grits are reddish in color, loosely consolidated, and resemble the Fountain formation (Carboniferous). On the ridge south of Grouse Mountain these grits locally rest upon rhyolite. This relationship is so similar to that between the rhyolite and the lake-beds of High Park, a few miles west of Grouse Mountain, that the grits of Straub and Grouse mountains have been referred to that lake-bed formation. Their thickness in Straub Mountain is 200 feet or more, though the unevenness of the granite floor makes an estimate difficult.

The phonolite mass of Grouse Mountain was laterally intruded into the grits at a time when they must have had a much greater thickness than at present. The plane of intrusion was very irregular, as shown by the map, cutting in places down to the granite, and there lifting rhyolite and grit, while in other places one or both of these formations were left between granite and phonolite. The phonolite of Straub Mountain is likewise an intrusion into the grits.

DESCRIPTION OF THE VOLCANIC CENTER.

Relation of tuff-breccia to granite.—The tuffs and breccias of the northern and eastern portions of the central volcanic area rest upon a surface of granite whose topography must be quite as irregular as the surface of to-day. This is shown by the course of the boundary line of the volcanics, and by the islands of granite and schist which project through the tuff and breccia. The isolated areas of tuff in Mineral Hill and Rhyolite Mountain also illustrate this relation.

From near Anaconda to Victor the contact plane is so steep in several places as to suggest that actual vents of the volcano are directly adjacent, and other evidence points to the same conclusion. The granite near these steep contact planes, especially at Anaconda and on the ridge south of Arequa Gulch, is very much shattered in a most irregular manner, as well as traversed by the usual fissure systems. The granite island of Ironclad and Bull hills is also very much broken up. A natural cause for this condition is to be found in the earthquake shocks attending the explosive eruptions of the volcano.

Brecciation of rock in place.—Many small bodies of massive volcanic rock in the central area correspond in their shattered condition to the granite of the contact zone. This is illustrated in Battle Mountain, Raven Hill, and Bull Hill. Many dikes are so broken up that the mass is really a breccia, although the dislocation may have been slight. The shock which shattered the massive rock doubtless affected also the loose fragmental materials and destroyed much of the bedded structure which may have existed in the tuff and breccia of the central area.

Relationships of the massive rocks.—The andesite of Battle and Big Bull mountains is certainly older than the tuffs which surround or overlie the patches now seen, for those tuffs are clearly made up largely of that same andesitic type. The other massive rocks cut the fragmentals as dikes or necks, but are not shown in sufficiently numerous masses to determine with certainty the sequence in all cases. Phonolite appears to have been the only rock erupted in several periods.

The nepheline-syenite body sends off arms which cut one of the masses of trachytic phonolite above the "Legal Tender" mine. But all the rocks except the andesite and basalt are closely allied, being very rich in alkalies and poor in lime and magnesia, and constitute one group characterizing the middle period of the volcano. The nepheline-syenite occurrence is of much importance as indicating that at the time of its intrusion the volcanic mountain was large enough to secure for this magma conditions of cooling suitable for the production of the granular structure. It is also probable that the mass lies within, or in close proximity to, the central conduit of the volcano.

Rock decomposition.—The rocks of almost the entire mass of the central volcanic area and of a large area adjoining on the northwest are very much decomposed. The prevalent form of this decomposition is a bleaching by removal of iron-bearing minerals, and a kaolinization or muscovitization of the feldspathic constituents. It is reasonable to assume that both gaseous and aqueous agents were active in producing this decomposition, inasmuch as the phonolite, the principal rock of the volcano, contains fluorine, chlorine, and sulphuric acid, and it is scarcely conceivable that the eruptions of phonolitic magmas containing these elements were not followed by intervals of fumarole and solfataric action. The porous zones in granite adjoining the phonolite dikes, due to removal of quartz and mica, testify to the action of agents connected with the phonolite magmas.

Age of the volcano.—An indirect chain of evidence indicates that the Cripple Creek volcano is of Miocene age. The late Eocene (Oligocene) lake-beds of Florissant are overlain by rhyolite seemingly identical with many other remnants, including those of High Park and Grouse Mountain. As stated above, the phonolite of the latter locality is later than the rhyolite, and, by inference, the volcano is, in part at least, younger than the Eocene, though there are no means of estimating the duration of the volcanic activity.

WHITMAN CROSS,

July, 1895. *Geologist.*

MINING GEOLOGY.

General statement.—Gold was discovered in the Cripple Creek region about twenty years before the recent developments. Two previous periods of mining excitement and exploration have occurred, one in 1874 and one in 1885; but, unlike the recent explorations, they ended without important results, for no paying mines were discovered.

The first really valuable discoveries were made in 1891. People flocked into the region and the district developed with remarkable rapidity. In the fall of 1894 the town of Cripple Creek, which came into existence in 1891, had a population of about 10,000, and this, added to the population of the neighboring towns and settlements which had sprung up, made a total of about 15,000. Over 100 mines and claims more or less developed were being actively worked, while several thousand claims had been located and partly prospected. The production of the district from 1891 to 1894, inclusive, has been variously estimated at from $5,543,967 to $7,000,000.

THE ORES.

General features.—The ores of the Cripple Creek district are almost exclusively gold ores. A little silver occurs in most of them, and its quantity is sometimes sufficient to be of importance, but usually it is insignificant. No other metals occur in any of the ores in quantities of commercial value. The ore consists usually of country rock more or less impregnated and replaced by quartz and other minerals, among which the most abundant are fluorite, opaline silica, kaolin, iron pyrites and other iron minerals, manganese oxides, and more rarely small quantities of galena, cerussite, possibly anglesite, malachite, acanthite, probably chalcopyrite, tetrahedrite, stibnite, sphalerite, calaverite, native gold, oxidized tellurium minerals, gypsum, calcite, and numerous other minerals in still smaller quantities. The stibnite, the sphalerite, and the copper minerals, including tetrahedrite, are very rare.

The ores often consist simply of country rock, either eruptive materials or granite, containing secondary quartz and associated minerals, instead of, as in many gold districts, and, in fact, as in parts of the Cripple Creek district, consisting of well-defined bodies of these materials. A characteristic ore of this district is an intimately mixed mass of quartz and fluorite, prominent on account of its brilliant purple color.

The gold.—The gold occurs in the ore as native or free gold, as telluride of gold, and possibly as auriferous iron pyrites, the last being the least important form. The usually superficial mode of occurrence and the physical condition of the native gold indicate that it has been largely derived from the telluride by oxidation, though some of it may have been derived from auriferous iron pyrites or may have been in the free state since it was deposited. Most of the gold at a depth is in the form of a telluride which has been determined by Dr. Hillebrand to be calaverite, though other tellurides may also occur. Iron pyrites is abundant, but rarely, if ever, so far as known, carries any considerable amount of gold.

Superficial alterations of the ores.—Superficial alteration has caused the oxidation, hydration, and leaching of certain minerals in the ore deposits, as well as the formation of sulphates, phosphates, hydrous silicates, tellurites or tellurates, and other oxidized compounds.

Value of the ores.—The value of the ores at present shipped from the mines varies from $20 to $400 per ton, though small shipments sometimes run up to several thousand dollars per ton. The district is at present essentially a shipper of only high-grade ores, but with increased facilities for treatment the large quantities of lower-grade ores that occur can be used and the production will be correspondingly increased.

MODE OF OCCURRENCE OF THE ORES.

General features of the gold deposits.—The gold of the Cripple Creek district occurs both in vein deposits and in placer deposits derived from the decay and erosion of the veins and country rock. Though the placers have produced considerable quantities of gold, the veins are far more important and supply most of the gold of the district. They generally occur in fissures in the country rock, which usually represent slight faulting. The veins intersect all rocks in their course, and have been formed mostly by a replacement along the fissures, and not, except to a very small extent, by the filling of open gaps.

THE FISSURES.

General features.—The existence of numerous dikes in the region indicates the presence of pre-existing fissures, so that fissuring action undoubtedly began sometime before the formation of dikes; in fact, it is natural to suppose that such action occurred during the whole of the eruptive epoch of the district. In some places the veins occupy these early fissures, but in a general way the vein fissures do not seem to have been the earliest ones formed, though many of them were produced before the dike action ceased. In most cases which have been examined, however, the fissures occupied by veins were formed after the intrusion of the dikes, as is shown by the fact that they intersect the latter.

The fissuring action affected both the volcanic area and the surrounding granite, so that the whole region is much broken by numerous fissures intersecting one another at various angles. In any single locality one general course is usually prominent, though intersecting fissures of less prominence are always present; and in some places there are two or more systems of parallel fissuring. The general course of the fissures carrying the veins of the district, like that of the dikes, varies from northeast to northwest; often it is nearly due north and south. Some of the fissures occasionally strike more nearly east and west, but in most of the important veins the more northerly trend is distinctly characteristic.

The fissures are usually represented by one main fracture with numerous subordinate parallel or approximately parallel fractures, though sometimes two or more main fractures occur close together; and frequently there is no one specially well-defined break, but a number of closely parallel fissures of about equal magnitude, giving the rock a minutely banded or sheeted structure and forming a fissured zone. The character of the fissures is much affected by the nature of the rocks they intersect, for they are sharper and better defined in the hard or brittle rocks than in the softer and more plastic ones.

The fissures as fault planes.—The fissures are usually the result of movement probably accompanied by a certain amount of faulting, as is proved by the occasional occurrence of fragments of rock in the better-defined fissures and the abundance of grooves or slickensides on their faces. The evidence so far obtained indicates that the faults in the vein fissures have throws varying from a fraction of an inch to several feet. Outside of the immediate Cripple Creek district, however, faults of much greater magnitude occur, sometimes with a displacement of over 1,000 feet, as described by Mr. Cross.

It has been suggested by some that faulting was the cause of the occurrence of the granitic breccia between the granite rim and the central area of volcanic breccia. This material forms a belt from a few feet to several hundred feet in width, and is seen at many places where the contact zone of the granite and the volcanic breccia is visible; but its character and mode of occurrence make it evident that it is due to volcanic action and not to faulting, though the material itself is more or less broken by later faults.

THE VEINS.

General features.—What has been said of the general mode of occurrence of the fissures holds true of the veins, which are simply bodies of secondary minerals filling the fissures. Sometimes the veins are single well-defined bodies of ore and sometimes they are thin parallel seams filling the fissured zones. They occur in all the rocks of the district—breccia, massive eruptives, and granite. The general character and mode of occurrence of the ore make it evident that the veins are, largely at least, a replacement of the country rock along very narrow fissures, which were hardly more than cracks, though occasionally the ore appears locally to have filled small open places along them. Every gradation can be seen, from country rock slightly impregnated with ore along a fissure, to country rock completely replaced and converted to a well-defined vein.

Relation of veins to dikes.—It is notable that the veins often follow dikes, either throughout their courses or, more commonly, for short distances, and that when a vein meets a dike, though it may cross it directly, it is likely to be deflected and to follow the dike for a greater or less distance. This association of veins and dikes is one of the prominent features of certain parts of the district, and is attributable mostly to the influence of the dikes on the vein fissures and in a less degree to their influence on ore deposition. Ore deposition was a sequel of the dike action, for it depended largely on the presence of heated rocks, and would be more likely to occur in the region of the latest eruptive rocks, which were the dikes, than elsewhere. The dikes may also have cut water channels existing in the country rock, and the water from such channels, thus forced up the sides of the dikes, might have caused ore deposition. Moreover, the shrinkage cracks formed in the dikes at their contacts with the country rock may in some cases have offered favorable places for ore deposition. These causes have doubtless been in some cases more or less effective in producing a connection between dikes and veins; but in most cases where veins follow dikes the association is clearly due to the purely mechanical effect of the dikes in directing the courses of the later fissures in which many of the veins were deposited.

Changes in veins and dikes at a depth.—It is often noticeable that near the surface both veins and dikes dip at angles different from those seen at a depth; while sometimes veins that occur in one well-defined fissure at a depth fork near the surface and appear in two or more separate outcrops. Both these phenomena can be attributed to the fact that the district is comparatively young geologically and erosion has not yet completely obliterated the original character of the upper parts of the formations. The fissures occupied by the dikes or veins were confined to the original line of breakage at a depth, on account of the superincumbent pressure, while nearer the surface this pressure was relieved, numerous transverse breaks of a more or less superficial character were encountered, and the fissures were more easily deflected or divided. Such effects are not seen in all parts of the district, or even in most parts, for erosion has usually removed all signs of them; but they are especially noticeable where erosion has been least.

Later movements in the veins.—After and possibly during the filling of the fissures with ore, more or less movement seems in some places to have occurred along them, for in some of the veins the mineral contents are cut by longitudinal breaks. A similar movement seems to have taken place also along the minor fractures that cross many of the veins, for the latter are sometimes cut by indistinct cross cracks.

Ore deposition in shrinkage cracks.—Sometimes cracks or sheeted zones occur in dikes at their contacts with the country rock, and follow all the curves in the meanderings of the dikes in a way that would not be likely to characterize independent and subsequent fissures. The sheeted structure here is probably caused by shrinkage of the dikes along the contact with the country rock during cooling. The shrinkage cracks are probably not so deep-seated nor so far-reaching as the fissures caused by the later dynamic disturbances, and therefore, when unaffected by such fissures, they probably have rarely if ever become the repository of important ore bodies.

PLACER DEPOSITS.

Since the time of ore deposition more or less erosion has occurred in the Cripple Creek district and the veins have been worn down in the same manner as the country rock. The gold in their eroded parts, by virtue of its greater specific gravity, has been concentrated with the gravels in the gulches and low places, thus forming the placer deposits. The country rock itself may contain some gold outside of the veins, and this may have supplied a part of the gold in the placer deposits.

The placers that have been worked lie mostly immediately north and west of the town of Cripple Creek, and occupy hollows in the amphitheater of hills surrounding the headwaters of the stream of Cripple Creek, though in many other places throughout the district smaller deposits occur and have been operated to some extent. The placers have been worked in many ways—by the pan, rocker, sluice, and by various forms of dry washers—but have been opened up only superficially. The water available for use in the wet processes is limited in amount, and therefore no attempt at "hydraulic mining" has been made.

SOURCE OF THE ORE.

General statement.—The gold and associated vein materials in the district have probably been derived from the volcanic rocks and, to a less extent, from the immediately adjacent granite; and they have probably not come exclusively from shallow sources nor exclusively from the immediately adjacent rocks, but from the whole area of rock in which the underground drainage was tributary to the fissures at the time of ore deposition. The sources of the gold and certain associated materials appear to have been the eruptive rocks and, to a less extent, the granite, an origin assumed more on account of the peculiar environment of the former during ore deposition than on account of any definite knowledge as to the relative amounts of gold in these rocks when in an unaltered condition. The concentration of gold in fissures requires not only a source of gold but also the reagents (generally hot solvent solutions under pressure) necessary to dissolve the disseminated metal, to carry it into the fissures, and there, by one or more of many methods, to deposit it. It is a noticeable fact throughout the Cripple Creek district that the richest veins occur in eruptive rocks or in granite in the vicinity of the vent or vents from which the eruptives were ejected. In such positions, as the result of subsiding eruptive activity, the rocks were subject to the action of hot waters impregnated with various solutions; and these waters seem to have been the reagents that dissolved the gold and caused its concentration in fissures. Hence the veins are rich in and near the areas of the vents and become poorer as distance increases; and hence also the eruptive rocks probably supplied most of the gold, while the immediately adjacent granite may have supplied a certain part.

The other vein materials accompanying the gold have probably come from similar sources, though often in a somewhat different manner. It is probable that the fluorine in the fluorite common in the district originally came into the fissures in a volatile or soluble form, such as hydrofluoric acid, or, more probably, as some of the hydrofluosilicates or as soluble fluorides, and there encountered solutions which carried carbonate of lime derived from the decay of the eruptive rocks or from other sources. The natural result would be the formation of fluoride of calcium (fluorite). If the fluorine had been previously in the form of hydrofluosilicic acid the precipitation of fluorite would have been accompanied by a deposition of silica; and as the two materials would thus be formed at approximately the same time the result would be the intimately associated mixture of quartz and fluorite known as "purple quartz," which is distinctly characteristic of the district.

Ore shoots.—In Cripple Creek, as in other gold districts, the gold is not uniformly distributed throughout the fissures in which the veins occur, but is concentrated in certain parts into bodies of ore of varying shape, size, and continuity, known as ore shoots or ore courses.

The shoots trend variously in the fissures, though often a general southerly pitch down and along the fissure is the most common. This is most noticeable where the course of the shoot is guided by certain transverse fissures. Elsewhere the shoots dip vertically, and more rarely a little to the north. They vary from one foot to several hundred feet in width along the fissures, and from a few inches to several feet in thickness. In some places they have a well-defined columnar shape, in others their forms are highly irregular; in some places they outcrop at the surface, in others their apex is many feet below the surface; in some places they extend continuously as deep as they have yet been followed, in others they end at a comparatively shallow depth, though in some cases these shallow shoots may be replaced by others at greater depth.

The localization of ore in shoots is due in some cases to a restricted circulation of ore-bearing solutions, guided by the more permeable places along fissures and by transverse fractures, while in other cases it is due to a variety of minor causes.

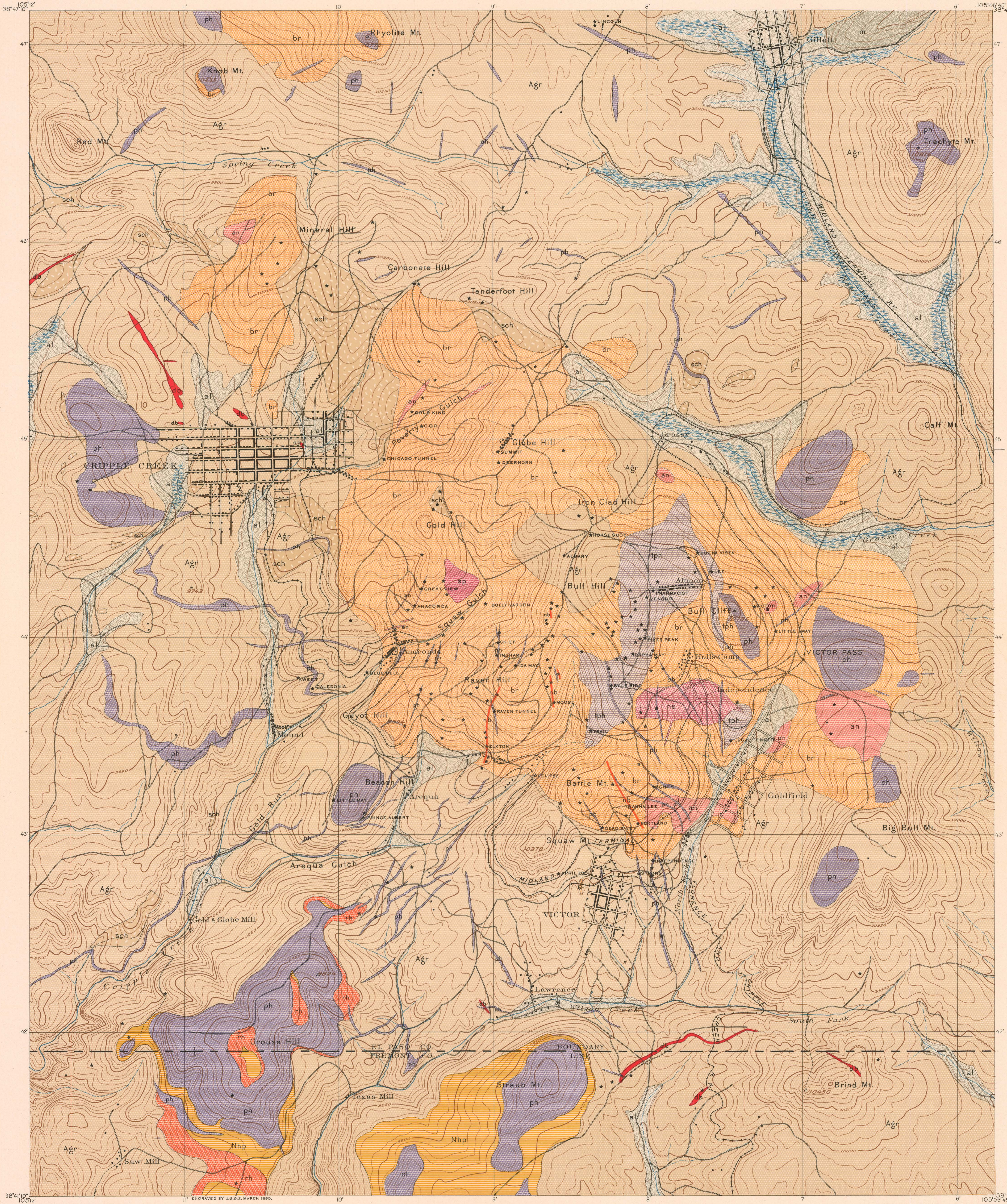
R. A. F. PENROSE, Jr.,
Geologist.

July, 1895.

U. S. GEOLOGICAL SURVEY.
CHARLES D. WALCOTT, DIRECTOR.

ECONOMIC GEOLOGY

COLORADO
CRIPPLE CREEK SPECIAL MAP



LEGEND

SUPERFICIAL ROCKS

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

PLEISTOCENE

- al — Alluvium
- m — Moraine

SEDIMENTARY ROCKS

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

NEOCENE

- Nhp — High Park lakebeds *(rudely stratified arkose gravels with rhyolitic debris in places)*

IGNEOUS ROCKS

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

- nb — Nepheline-basalt *(occurs only in narrow dikes)*
- ns — Nepheline-syenite
- sp — Syenite-porphyry
- tph — Trachytic phonolite
- ph — Phonolite *(dikes and massive bodies of several different dates)*
- an — Andesite *(includes several types of different dates)*
- br — Tuff and breccia *(made up mainly of andesitic debris, with granite and phonolite locally abundant)*
- rh — Rhyolite
- db — Diabase *(narrow dikes in granite or schist)*

ALGONKIAN

- Agr — Granite *(reddish biotite-granite, both coarse and fine-grained, locally gneissoid)*

ALTERED ROCKS

(Areas of Altered rocks are shown by patterns of short dashes)

- sch — Schist *(detached masses included in granite)*

SPECIAL SYMBOLS

★ *Gold mines and prospects*

Henry Gannett, Chief Topographer.
Triangulation by E. M. Douglas.
Topography by W. B. Corse T. M. Bannon and E. M. Douglas.
Surveyed in 1894.

Scale $\frac{1}{25000}$

1 ½ ¼ 0 1 Miles

1000 500 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 Feet

1 ½ 0 1 2 Kilometers

Contour Interval 50 feet

Datum is mean Sea level

Initial position is Pikes Peak as determined by Hayden Survey

Edition of May 1895.

Geology by Whitman Cross.
E. B. Mathews, Geological Assistant.
Surveyed in 1894