EXPLANATION.

The Geologic Survey is making a large topographic map. A large geologic map of the United States is being prepared in the form of a Geological 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 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 a part of hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate the degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. These lines are called contours, and the constant vertical space between two such contours is called the contour interval. The 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:

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 level; and so on with other contours. Contour lines occurring near any two points occur at elevations above the lower and below the higher contour. Thus the contour at 150 feet falls precisely on the edge of the terraces, while that at 200 feet lies above the terraces; therefore all points on the contour are shown to be more than 150 feet above sea level. The summits of the higher hill is stated to be 670 feet above sea level; accordingly the contour at 600 feet surrounds it. In this figure in which there is no possible certainty, 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 divide the land into forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they indicate roughly the outward surface of the contours, and the height of the ground above. The relations of contour character to form of surface can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between any 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 1:600,000, the contour interval may be 200 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 so-called 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 many 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.

SEDIMENTS.—The area of the United States (without Alaska) is about 9,030,000 square miles. On a map 240 feet long and 160 feet high the area of the United States would cover 3,000,000 square miles. Each square mile of ground surface would be represented by a corresponding square inch of map surface, and one line inch 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 map 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 wide would have a scale of "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 the 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 the second \( \frac{1}{63,360} \), and the largest \( \frac{1}{24,000} \). These correspond approximately to one mile of map surface to one mile of natural surface; one mile of map surface to about four square miles; and one mile of map surface to about one square mile. At the top of the map sheet is shown a fraction, and it is further designated by a "bar scale," a line divided into feet, inches and tenths of an inch.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 6 feet long and 4 feet wide. Two such sheets side by side on one of the larger scales it would be either two times or four times as long and high. To make it possible to fit such a map comfortably into sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of

\[ \frac{1}{24,000} \]

contains one square degree (that is, represents in area one degree in each direction); each sheet on the scale of \( \frac{1}{63,360} \) contains one-sixteenth of a square degree; each sheet on the scale of \( \frac{1}{24,000} \) contains one-fourth of a square degree. These sheets are numbered nearly to 4,000,100, 250 and 200 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 geographical position, 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 further distinguished according to their relative ages, for rocks were not formed at all times, but from age to age in the earth's history, new types of rocks were formed in different localities, for the conditions of their deposition at different times and places have not always been alike, and the various rocks have been deeply contorted by the forces of the earth. Where beds of sand were buried beneath beds of mud, sedimentary rocks may form under conditions; then fossils are found which help characterize the rocks. In the map of the United States, a guide to which shows which of two or more formations is the oldest. When two formations are represented on the map, it is impossible to observe their relative positions, the characteristic fossil type found in them may determine which rock is older. The fossils found in one formation may be repeated in others.

A map of the United States on the scale of \( \frac{1}{24,000} \) will show most of the fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the living types of creatures on the earth multiplied. But during each epoch these lived peculiar forms, which did not exist in earlier times and have not existed since, are characteristic types, and they define the age of any bed of rock in which they are found.

We do not always occupy the positions in which they were formed. When they have been disturbed it is often difficult to determine their geological position; then fossils are a guide to which of two or more formations is the oldest. When two formations are represented on the map, it is impossible to observe their relative positions, the characteristic fossil type found in them may determine which rock is older.

Acres of sedimentary rocks are shown on the map 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 color (from new to old), with the color and symbol assigned to each, are given below:

<table>
<thead>
<tr>
<th>Period</th>
<th>Color</th>
<th>Pattern of Parallel Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precambrian</td>
<td>Yellow-buff</td>
<td>Not shown</td>
</tr>
<tr>
<td>Lower Cambrian</td>
<td>Olive-green</td>
<td>Linear</td>
</tr>
<tr>
<td>Upper Cambrian</td>
<td>Blue-green</td>
<td>Linear</td>
</tr>
<tr>
<td>Lower Silurian</td>
<td>Gray-blue</td>
<td>Linear</td>
</tr>
<tr>
<td>Upper Silurian</td>
<td>Gray-blue</td>
<td>Linear</td>
</tr>
<tr>
<td>Lower Devonian</td>
<td>Green-blue</td>
<td>Linear</td>
</tr>
<tr>
<td>Upper Devonian</td>
<td>Green-blue</td>
<td>Linear</td>
</tr>
<tr>
<td>Lower Carboniferous</td>
<td>Gray-blue</td>
<td>Linear</td>
</tr>
<tr>
<td>Upper Carboniferous</td>
<td>Gray-blue</td>
<td>Linear</td>
</tr>
<tr>
<td>Lower Permian</td>
<td>Oil-shale</td>
<td>Linear</td>
</tr>
<tr>
<td>Upper Permian</td>
<td>Oil-shale</td>
<td>Linear</td>
</tr>
<tr>
<td>Lower Triassic</td>
<td>Orange</td>
<td>Linear</td>
</tr>
<tr>
<td>Upper Triassic</td>
<td>Orange</td>
<td>Linear</td>
</tr>
</tbody>
</table>

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 symbol; 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 further distinguished by 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 printed in the color of the pattern.

Fossils.—These are crystalline rocks, which have cooled from a molten condition. Fossils have been in existence so long that the earliest possible rocks are those formed both at the molten and fluid stages, where they congealed, forming dikes and sheets. Sometimes they
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° and 39° north latitude. This region is 14 miles north and south, and 27 miles wide, and hence contains 8931 square miles. It includes portions of Fremont, El Paso, Lake, and Gunnison counties.

TOPOGRAPHIC FEATURES.

Relief.—The area is almost wholly mountainsous. On the eastern side the crest of the Colorado range, including its summiting point, Pikes peak, and including also a part of the southern end of this range as it dies out en eochelon. The central and western portions of the district form essentially a high plateau, penetrated on the south by the narrow valley which 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 14,500 feet above sea level. On the east the drainage basin of the range extends from Pikes peak to the Platte river canyon, shown on the structure section sheet of the atlas.

To the south the plateau is deeply scored by many canyons of comparatively recent erosion, which cut nearly to the bed of the stream, but which do not extend far back above 6,000 feet. The greatest elevation is that of Pikes peak, which is lost in the drift at 10,000 feet, and the stream courses through the southern portion of the area at about 5,000 feet above sea level.

Drapery or a network of ridges and furrows is produced in the district by tributaries of the South Platte and Arkansas rivers. In the northeastern corner of the district the South Platte river makes a sharp bend on the map and cuts its way through the Eleven Mile canyon, curving in its course from east to west. Almost the entire northern third of the district is drained into the Platte, either directly, by Twin creek, or through branches of Troux creek which passes north of Garden park through Marshall island.

In the northeastern corner of the district is the head of Fountain creek, which courses south of its junction with the Arkansas river. The remaining two-thirds of the area is drained by the tributaries of the Arkansas, the most important of which are the South Platte, Beaver creek and Cannon creek. These may be described as a series of connected deep canyons in the plateau. The Royal George of the Arkansas approaches at its upper end to within one mile of the southern map line, south of West Eight mile park.

Cultivation.—In spite of its proximity to the early settled portion of Colorado the region 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 railroad the old stage line of the Colorado Springs through South park to Leadville and Fleront has been used as a toll road.

The plateau region is arid but affords extensive grazing lands for cattle. In Garden park and in Grover creek in the area of the large igneous rock deposits on the north side of the range growing.

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 replaced by a hardy and vigorous growth of aspen. Over the general plateau country there is a struggling growth of spruce and of pine on ledges and in the lower ground. Along the axis of the main divide, pine, cedar, and aspen are quite uniformly but sparsely present. Various species of cactus and other plants of dry climates are found in the lower portions of the area.

DESCRIPTION OF ROCK FORMATIONS.

A preliminary to a general sketch of the geology of the Pikes peak district it is necessary to state the various rock formations entering prominently into its construction 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 geologists the leading metamorphic rocks, being the rocks that have been most intimately connected with the granite which the main theme will be described as later. The latter 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 granites, and the gneissoidal rocks derived from it. There are several types which are plainly products of different intervals, and many varieties whose significance can be determined only after long study of a large field. In the classic or local varieties of a given rock body, often show differences among them as masses of unidentifiable origin. The chemical composition of most of the different granites is nearly uniform, and marked differences arise chiefly from differences of color or else of 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, and 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 principal types must suffice. These are the types which are especially prominent as occurring in very large bodies, and contrasting distinctly in structure.

The Pike's 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 granite, in most places of pronounced red color due to a pigment of hydrous iron oxides which conspicuously impregnates the feldspar. Its main constituents are the potash feldspars, microcline and orthoclase, often intergrown along the manner of perthite, with plagioclase, quartz, biotite, zircon, apatite, alluvtie, rutile and other accessory minerals. These are present in more or less constant.

The feldspar is the strongly predominate element of the rock and the variations in its development cause the principal structural modifications. Some times 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 arise a perthitic structure and the rock becomes a granite-porphyry. This type is well developed in the Cripple creek, east, and in other places. Biotite occurs in single leaves, large or small, or in clusters of small flakes and is so frequently intergrown with feldspar that it is difficult to define grading insensibly but rapidly into feldspar that there can be no question of the derivation of most of the granite from the biotite granite under the influence of a great pressure.

The oldest 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, and finally split into the "crespe" or flat flakes, with mica leaves wrapped about them. This change can sometimes be seen within two or three miles of Pikes peak and is, at this stage, a metamorphism of gneiss is marked by the parallel position of the mica leaves, muscovite being commonly associated with feldspar in the intergranular masses. Different stages and no abundant that the expression "gneissoidal granite" is applicable to the rock of considerable areas.

Gneisses of doubtful origin.—Occurring with the principal Alkamin quartzite, or as separate inclinations in granite, are gneisses which are not demonstrably derived from granite. These bodies or gneissic bodies, which are rich in mica, or show a marked alteration of dark and light colored minerals. Some of them have been developed in almandine and grade almost into some of the Alkamin quartzites impregnated with secondary minerals. It is quite probable, although the development of gneissic bodies represent the products of metamorphism of Alkamin strata, and also the true Archean gneisses upon which the Alkamin beds were deposited.

Silts.—Rocks possessing so perfect a degree of foliation that they may be properly termed silts are of very subordinate development in this district. In some places on and near the placers the gneissic structure gives way to a fine schistosity, muscovite replacing feldspar, and a mica schist results. But the most pronounced silts are found as inclinations in granite, notably at Garden park, trending northwest. There seems to represent earthy alkalin quartzites metamorphosed by a great development of muscovite, or of muscovite schist, trending parallel.

Chloritic or amphibolite silts locally result from the squeezing of dikes or small masses of diabase that have been injected, as may be seen near Cripple creek and in the southwestern corner of the district.

SEDIMENTARY FORMATIONS.

ARCHAEOAN PERIOD.

The distinctly stratified quartizes and allied rocks found as inclinations in granite and gneiss are obviously the oldest sedimentary rocks of the district and are known locally as quartizes, or of a similar nature, till, shales and sandstones, and are therefore not given a formal name. The largest and most homogeneous group of this nature is shown in Wilcox gneiss. Here there is exposed a section nearly 4,000 feet in thickness of white or bluish gray quartizes, standing on edge and exposed on the strike for about 5 miles. They are cut off on the southeast by granite, and at the northeast pass under the sedimentary rocks of Garden park. Granite dike penetrates these at places. A narrow belt of quartzite appears in Cooper mountain, east of the Platte river.

Another important mass is that forming a ridge west of Florissant, a portion of which is known as the Florissant formation. This large mass consists of flinty quartzite with a small and variable amount of feldspar. This mass is also cut by granite dikes and is nearly the same thickness as the Cripple creek.

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

The base of the known Palose section in Colorado is an upper Cambrian quartzite which extends across the range rests on the granite and gneiss containing these quartzite inclusions. In the light of present knowledge concerning pre-Cambrian rocks of the West it is deemed better to refer to the included sedimentary rocks to the Alkamin rather than to assume that these are "pre-Cambrian," as that term is generally understood. The presence of fluvial, cryotropical, and others that texture to presence of fluvial in large amount of the streams which are covered by quartzite. Cryotropical 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 GRANITES TO METAMORPHIC ROCKS.

The principal 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, and finally split into the "crespe" or flat flakes, with mica leaves wrapped about them. This change can sometimes be seen within two or three miles of Pikes peak and is, at this stage, a metamorphism of gneiss is marked by the parallel position of the mica leaves, muscovite being commonly associated with feldspar in the intergranular masses. Different stages and no abundant that the expression "gneissoidal granite" is applicable to the rock of considerable areas.
in Garden park has yielded a ribbit, *Pseudopteronia*. These forms indicate upper Cambrian deposits, but the extreme thinness of the beds in question and their variable location make any detailed representation on the map impracticable and they are therefore included with the Mannion limestone.

**Silurian Period.**

The Silurian section of the upturned zone between Canyon City and Garden park has been studied by W. W. Willard, and divided into three important formations, distinguishable by their rich invertebrate faunas and also by stratigraphic divisions to which he has given the names here used. [8, 9]

**The Mannion limestone.**—This is the lowest Silurian formation, and is a succession of fine grained, pink or reddish dolomite, less than 100 feet thick, and contains Ophiacta, Geniculata, and a few other invertebrate fossils characteristic of the lower Silurian formation in the section at Manion Springs and in Manion park, whence the name is derived. This limestone is best seen in the upper part of the 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 park is closely bedded, with the north, partly through probation, partly by erosion preceding the Fountain period. The formation is not dolomitized in this vicinity.

**The Dakota sandstone.**—This very characteristic formation is made up predominantly of fine and even grained, subaxial sandstone in alternating beds of light gray and pinkish or variegated colors, with a few bands of dark red or purplish sandstone. They are about 100 feet thick. The lower part is sometimes calcareous and locally develops into a thin, fine grained sandstone. This horizon is characterized by numerous plates and scales of goniatites and by a choral sheet of a solinidae, which occurs in the invertebrate fauna indicating close correlation with the lower Trenton of New York. The fishes of the Hardin formation are the oldest known, and belong to types not elsewhere found below the Deception.

The Hardin sandstone is not found in Manion park, or at Manion Springs, and has not been identified at any other locality, but similar fishes have been discovered in the same formation as in the neighboring formation in Garden park. The Hardin sandstone rests with apparent conformity on the Mannion limestone, but on the southeastern edge of the park it is not as distinct. The latter is more or less overlapped, so that the Hardin beds locally on the basal cherty limestone (Cambrian), or even on graptolite and ripple beds pillared toward Canyon city, the Hardin beds rest on graptus, apparently by overlap. The name given the formation is that of a stone quarry near Can-

**The Fountain limestone.**—Succession of the Hardin sandstone with apparent conformity there occurs a bluish gray or pinkish dolomite of uneven grain, sometimes arenaceous, which gives rise to a very rough weathered outcrop. It forms the pediment of the gently inclined masses at the north end of the Garden park bay, and of the steep dips slope southward toward the north end of the park. There are many small coves and hollows in the cliff face of this rock.

The thickness of the Fountain limestone in the park is about 100 feet, but it increases southward, and near Canyon city reaches a maximum of 270 feet. This is partly taphonomic. It is a dark, brownish, black, and a high fossiliferous member not seen in Garden park.

The Fountain limestone of Garden park is especially characterized by the chain coral *Hyalasites obtusus*, and also contains a large invertebrate fauna like that of the upper part of the Western Desert formation. The formation is not as well exposed, and the evidence has yet been found to show the correctness of such a conclusion. It is deemed more probable that the lower part of the *Red beds* belong to the Carboniferous, than that the whole complex is Triassic.

**Jurassic Period.**

**The Morrison formation.**—The earliest Mesozoic sediments are prevailingly greenish, pinkish or gray shales and marls. Sandstone occurs at the base and is intercalated at numerous horizons in the upper part of the series with varying development of the total thickness. 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, *Rhinocerosaurus*, and many Dinosauria, many forms of which have been described by C. O. Marsh. Fresh water shells seem to be the most characteristic of the sea of the sea in which the rocks were deposited. *Gyrinus* is locally developed and becomes prominent near the top of the mountain, and is largely responsible for the base of the formation. The name is given from the classic locality at Morrison, near Denver, the type locality of *Gyrinus* in America, by G. H. Eldridge, in the description of the Cretaceous Butte sheet.

**Triassic Period.**

**The Dakota sandstone.**—The Morrison formation is followed with apparent conformity by about 500 feet of fine white or gray sandstone, the Dakota sandstone, usually friable and of uniform texture. At or near the base there is usually a fine conglomerate, the pebbles of which consist of gray, colored, yellow, or white quartz. Midway in the series there are several layers of dark gray, locally developed into pure fire clay of economic importance. Where these layers are interbedded, the Dakota characteristically forms the cap of heavy ridge parts, or of gentle mesaslike slopes, as at the type section of the Dakota. This formation is seen above the Morrison in Twelve Mile park, and in small remnants upon the granite to the south.

**The Colorado formation.**—The Dakota is succeeded by a series of dark or gray shales with a complex of fine limestones beds about midway in the series, and with a brown sandstone near the top. The formation is developed on West Wilson creek, and in the southern border of the map is about 500 feet. These shales represent the Benton division of the Colorado. They are succeeded by limestone complex, the thin layers of which are characteristically separated by thinner shale seams. Above this limestones there come several hundred feet of yellowshale, more or less arenaceous, and the two divisions comprise the Niobrara formation as it is characterized by its great thickness, 100 feet or more, along the Colorado river. The formation is best developed in the valley of Eight Mile creek. In Eight 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 limestones 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 yellowbrown arenaceous shales, containing an abundance of clay lime concretions. It is probable that only the Pio or lower division of the Montana is represented in this park.

**Recent Period.**

**The Florissant lake beds.**—The largest part of recent deposits, the most of the district is that above the Florissant. As shown by this map the lake occupied a long, narrow depression now traversed by the Royal Gorge through western tributary, Grape creek, and extending for many miles up one of the sides 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 entirely clay, and were 50 or 60 feet thick, occasionally showered upon its waters, forming soft and crumbling tufts and mud shales. The total thickness of strata now preserved is only about 30 feet, mainly in thin layers of very fine grained, alternating every few inches with coarser ones, while the channel beds in several thousand feet in thickness in some places.

The most prominent material in sediments is charcoal in characteristic deposits of benton and ryholites, and probably belongs to the earliest eruptions of the volcanic center which lies westward of the map area. The dark, basaltic breccias, and other remnants of ryholite 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 subaqueous fauna and flora of the period. The insect faunas preserved is particularly interesting. Many thousand specimens have been collected since the discovery of the beds and the material has been but partially described (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, fish, and mollusks, and a very large fossil flora. In the flora 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 Ollie creek, on the granite plateau, lies High park, a small plateau containing remnants of a series of local sandstones and conglomerates lying either upon granite or upon a thin ryholite flow. The conglomerate is characterized by pebbles of the extremely hard Argonikite 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 breccias, as they contain no debris of such material. In the hills east of High park are seen between ryholitic and phololithic flows. A very small remnant of the High Park conglomerate is present on the ryholite sheet capping Red ridge, 500 feet above the present level of high park.

**The alpine lakes.**—In the valley of Ollie creek about Airview we have the lobe basaltic basins confused to the present valley of Ollie 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. The lower one is apparently younger than the others, but older than that of High park. No fossil remains have been found in the deposits.

**Insect fossils other than granite.**

**ANCIENT DRIFT ROCKS.**

**Diatom and euglenas.**—The granite 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 graphic structure technically called opilite is commonly well developed. Some of the dikes are rich in olivine.

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into hornblende and in zones of shearing the dike rocks are locally altered into amphibolite or chloritic schists.

**Basic Breccia and Agglomerate.**

Occurring over 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 aereal formation, building up mountain masses 2,000 feet and more in height upon the granite plateau.

**Mechanical constitution.** The fragment formation in question has a nearly horizontal bedded structure varying in distinctness in different localities. In texture it varies from fine and uniform 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 not visible in the outcrop and becomes prominent only in large exposures. The structure is most clearly seen in Saddle mountain north of West Four Mile creek, whose masses are chiefly made up of this material.

The greater part of the agglomerate is essentially a mixture of heavy basaltic agglomerate in which large and small fragments are predominantly mingled. In some places the larger fragments are 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 sorted by water and the constitution of the mass is that of a characteristic specialization of the great central area of very great centers of violent and repeated volcanic outbursts.

The agglomerate is penetrates by numerous narrow sheet dikes of compact basalt, and the same rock in local intruded within basalt masses beneath in several localities. These small bodies could not have been represented upon the map, they are especially abundant in Saddle mountain and the vicinity.

The greater part of the agglomerate is soft and crumbling. An exception to this rule is the hard basalt wall consisting of 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 purple color.

**Petrophysical character.** The lower part of the agglomerate or breccia is essentially 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 compositions as the normal basaltic cuttings the breccia. The dike is replaced to a large extent in some of the rocks by the substance of the andesite characterized which has been called iddingsite.

**Structures of the rocks of this series vary greatly.** Many are porphyric or vesicular 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 anesitic types appear in which olivine is replaced by hypersthene, and some normal anesitic-textured are found. Fragments of trachyte and of hornblende-andesite are also mingled with the basalt rocks in the upper beds of Metzger mountain, and in the district south of High creek.

In the mass of the southwestern corner of the district are several thin flows of olivine-bearing anesite similar to the fragments of some of the upper parts of the agglomerate.

**Kanaye 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 either older than the breccia, for the relationship is not always clear. These andesites may be divided into three classes, those characterized by andesine, and those containing chlorite, etc.

**Ambler-andesite.** This type forms a group of massive rounded dikes at the head of West Four Mile creek and constitutes the main mass of Tower mountain. The rock is compact, and porphyritic, with abundant crystals of plagiolase 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 nearly uniformly dark rock as the pyroxene andesite of the breccia.

**Hornblende-andesite.** Upon this broad area and many rocks vary 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 andesite as well as the basic breccia, and are also found as shears and fragment masses.

Usually plagioclase, hornblende and biotite are prominent in distinct crystals in a predominant dense gray groundmass which may contain quartz or tridymite. The basic type of the dike is about 130 of the sheet about Cap rock few have very distinct crystals of any kind and the dark gray predominate groundmasses are much trachytic.

**Adirondack Breccia.**

**Rocks hills area.** The smaller of the two areas of andesite breccia and tuff represented upon the map, situated in the Bar hills south of High creek, consists of a massive diabase of 5 fuses of fine-grained to massive sandstone in granite. They occur on the south side of the mountain past the middle boundary, and some of the larger ones are represented upon the map.

The dike vary from a few inches to 300 yards in diameter and are connected by cross fractures. 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 south of the area of the map.

The material of the dikes is an uniform fine-grained sand, composed almost wholly of quartz particles, with a very little feldspar, indurated and colored dull red by flakes of limonite in detail at any point. They were indicated to known in the oven cavities, and no geologic connection can be made out between the dikes and sedimentary rocks. The dike 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 units correspond very closely to the development of certain topographic features. Thus the mass of Peaks 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 plateaus and in the deep valleys between the small lake basins on the plateau. The greater formation of some of these formations is indicated by facts which carry from the complex map of the mining district.

**Areas of Granite and Gneiss.** Granite and gneiss constitute the great bulk of the Colorado range throughout its length, but their geologic relationships have never been studied so closely. They are present in the adjoining areas of the young and the old volcanic rock in the mountains and the canyons are especially full of fragments of schistose rocks. Tonsmulline-bearing veins are very common and in many places can be observed.

**Western central area.** The foundation upon which the granitic breccia of this region rests is almost entirely of fine grained, massive, reddish granite characterized by very numerous inclusions of quartz, but containing less feldspar and micaceous minerals, and finely laminated gneiss of metamorphic structure. There are also dark hornblende gneiss in slight development, which appear to be derived from ancient igneous rocks. In the upper part of the mountain there is, however, considerable evidence of fine-grained granite type gneiss which prevails in the granite belt, but the reddish mountains bounding the plateau are chiefly of the coarse grained porphyritic granite in which the gneissoidal structure is very commonly developed.

**Southern area.** The transition from the massive porphyritic granite of the central area to the syenite of the western area is very gradual. In the upper part of the mountain there is, however, considerable evidence of fine-grained granite type gneiss which prevails in the granite belt, but the reddish mountains bounding the plateau are chiefly of the coarse grained porphyritic granite in which the gneissoidal structure is very commonly developed.

**Creek district.** The plateau extending southward from Creek Creek is generally characterized by coarse grained granite and gneissoid forms derived from it. A fine grained massive granite, the older of the two, is present in the region out as the deep canyon of East Beaver creek. In Eight Mile canyon there are many beautiful exposures of fine grained dikes and interbedded rocks in a mountainous region. In the eastern part of the Creek 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.

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Alaskan quartizes are shown in the granites and gneisses of this district, the most prominent ones being in Cooper mountain, and in Eight Mile canyon at McConnell's camp.

Areas of sedimentary rocks.

Southwestern area.—In the southwestern corner of the district, where both the mountains and the plains are upturned at the base of the granite mountain mass, the characteristic foot-hill structure is pronounced. The rock formation here exposed is the Dakota sandstone forming mesas sloping gently to the south but presenting a steeper slope toward Beaver creek, which cuts through it. The gentle dip of the Dakota causes it to form mesas, and these are in turn cut by parkdale and canyon city sheets. The Morrison formation occurs in a narrow zone below the Dakota cliffs 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 erosion produce little park areas. The dip of these beds is 10° to 15°, except for the lower strata which dip 50° or more, and some distance up on the foot-hill ridges. A rather narrow band of the Harding and manitou formations extends back on the ridges to variable distances.

To the west of Eight Mile canyon the silexian rocks form a rather flat upland, the broad breccia formation above already protecting the base of the mountain. The prominent outcrop is that of the Siltstone which is here present above the Harding sandstone.

Creeking the lower part of Eight Mile canyon is an overhanging front with a northeast-southwest trend and steep dip which parallels a fold in the rock, with a flat front at either end, but has produced a considerable dislocation in its central part, bringing up the crystal face very prominently on the southeastern side of the Garden park.
Cambrian to the Eocene it seems probable that the coastline 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 cover a part of what is now mountainous territory.

*Geographic 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 Millipap (Carboniferous) limestones and the Fremont (Silurian) limestones. *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 Millipap limestones 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 ascribed to the upper Carboniferous the preceding interval embraced very probably the middle Carboniferous, and was correspondingly longer if the grist belong to any later period. There is no evidence to indicate that the known Fountain beds were composed 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 grists 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 ascribed by other geologists to the Penno-Carboniferous and Triassic during which thick sediments accumulated elsewhere in the Rocky mountain region. If deposits were formed during three periods in this region they were eroded before the subsidence preceded 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 Horrano park at the south end of the Wet mountains it is known that a further movement of this character took place after the Bridgey (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 those great orogenic 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.

*Erosion.*—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 morainic 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 superficial formation which is apparently glacial drift, consisting of small rounded boulders and gravel. Pluvialite and various other eruptive rocks of the region are represented among these boulders. Very similar material also appears on the plateaulike 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.*—In the vicinity of Bridgey and Summit 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.

*Evolution.*—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:


2. *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 105 to 212.

3. *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 41 to 46.


*Whitman Cross,* Geologist.

June, 1894.
GENERAL GEOLOGY.

The field work upon the Cripple Creek special map was done in September, October, and November, 1894, after the publication of the Titusville geologic section. The special map is larger than the geologic map, and the details of the geologic map are more complete and accurate.

The outline of the central volcanic area is practically unchanged, but the formation within it has been much uplifted. The uplift has been accompanied by a rise of the ground surface.

The central volcanic area is the most complex and the most interesting geologically. It is also the area of greatest economic importance, because the gold deposits are there most prominent.

The rock formations in the Cripple Creek area are characterized by the presence of massive quartz veins and breccias. These rocks are often altered to a fine-grained material, which is known as "hedral" or " brecciated".

The quartz veins are often found in association with other minerals, such as pyrite and chalcopyrite. These minerals are important economically, as they contain copper and gold.

The breccias are characteristically found in the center of the volcanic area, and are often associated with the quartz veins.

The breccias are also a significant source of gold, copper, and silver. The mineralization is often accompanied by the formation of geodes, which are filled with a variety of minerals.

The breccias are often faulted, which suggests that they were formed by tectonic processes. This is supported by the occurrence of faulted breccias in other volcanic areas, such as the Tertiary volcanic rocks of California.

In summary, the geology of the Cripple Creek area is characterized by the presence of massive quartz veins and breccias, which are often altered to form "hedral" or " brecciated". These rocks are important economically, as they contain copper, gold, and silver. The mineralization is often accompanied by the formation of geodes, which are filled with a variety of minerals. The breccias are often faulted, which suggests that they were formed by tectonic processes.

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MINING GEOLOGY

General statement.—Gold was discovered in the Cripple Creek district about 1890, and the mining operations of the last quarter of the century have been the most important developments. Two previous periods of mining excitement and exploration have occurred, one in 1874 and another in 1885; but unlike the recent explorations, they ended with- out 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 rapidly. 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, as previously mentioned, was largely composed of the neighboring towns and settlements which had sprung up, made a total of about 15,000. Over 100 mines and claim entries 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 $5,453,867 to $7,600,000.

THE ORE

General features.—The ore of the Cripple Creek district is almost exclusively a gold ore. A little silver occurs in most of them, and its quantity is sometimes sufficient to be of import- ance, but usually it is not enough to make it worth while to replace quartz and other minerals, among which the most abundant are fluorite, quartz-sulfide, calcite, and dolomite, iron pyrites, galena, molybdenum, manganese oxides, and many rare small quan- tities of galena, cermite, possibly angleite, molybdenite, and scheelite. The fluorite is commonly associated with the other minerals in small quantities. The sphalerite, chalcopyrite, and pyrite are rarely seen.

Superficial alterations of the ores.—Superficial alteration and weathering have caused the oxidation, hydration, and leaching of certain minerals in the ore deposits, as well as the formation of sulfates, phosphates, hydrate silicates, tellurides or tellu- rites, and other oxidized compounds.

Value of the ores.—The value of the ores at present shipped from the mines varies from $85 to $100 per ton, though small shipments sometimes run up to several hundred dollars per ton. The district is at present essentially a skinner of 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.

SOURCE OF THE ORE

General statement.—The gold and associated vein materials in the district have been probably derived from the volcanic rocks and, to a less extent, from breccias and other anticlinal structures. The most abundant of these materials, and they have probably not come exclusively from the shallow sources nor exclusively from the breccias, have been derived from the whole area of rock in which the underground drainage was tributary to the fissures at the time of ore deposition. The course of the gold and certain associated materials appear to have been the eruptive rocks and, to a less extent, the granite, as the former assumed more control 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 those rocks when an under- ground condition. The concentration of gold in fissures requires not only a source of gold but also the agents (generally hot solvent solutions under pressure) necessary to dissolve the disseminated metal, to carry it into the fissures, and then, 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 granitic dikes, and that the richest veins in breccias or veins from which the erupitives were ejected. In such positions, as the result of sub- sedimentary activity, the eruptive rocks were subjected to the action of hot waters impregnated with various solutions; and these waters seem to have been the agents that dissolved the gold and carried it into the fissures by the process of solution.

Changes in veins and dikes at a depth.—It is often noticeable that near the surface both veins and dikes are filled withargentiferous pyrite, but at a depth in the country rock, the fissures and dikes may be filled with quartz, or there may be no visible pyrite at all. Pyrite, at least, is often found at the top of the fissure or dike, whereas it is very rare in the country rock at a distance of several hundred feet below the surface of the mine. This change in the character of the fissures and dikes is probably due to the action of hot waters impregnated with various solutions, and these waters seem to have been the agents that dissolved the gold and carried it into the fissures by the process of solution.
pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from fissures at subordinate points and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

The rocks that form the surface 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 map by patterns of triangles or rhombus printed in bright yellow. 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) Atheral 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 under the pressure of the earth's crust, forming rocks of the same type as those formed by metamorphism. Metamorphism is produced 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 slates; but when rocks of any class are found in thin layers that are due to pressure they are called schists. When the cause of the thin layers of metamorphic rocks is not known, they are called schists. When 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 Archean, 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 placed against any type of background. If the rock in a shist the dashes or outlines may be arranged in wavy parallel lines, or even twined together to form a network of the formation is crossed by the geologic 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 outline of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude to be recognizable. It may guide the traveler, who can determine in advance or follow continuously on the map road along strange highways and byways. It may serve the inventor or owner who desires to ascertain the position and surroundings of property he has bought or sold.

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

The strata of the great geological ages, and homes, and serves all the purposes of a map for local reference.

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 you should look for that color and pattern in the legend, where you will find the name and description of the formation. If it is one of the larger groups, you may be able to locate it in a map corresponding to another period after you have learned the position, evidently younger than the underlying formations, and the bedding and deformed fold and the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata rest upon an eroded surface of older strata or upon their upturned edges, the relation between the two is conformable, and their surface of contact is unconformable.

The third group of formations consists of crystaline schists and igneous rocks. At some period of their history the schists have been plastically deformed 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 active 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 Sheet are related to the maps as the section in the figure is related to the landscape. The diatruses in the section correspond to the actual slope of the ground along the 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 maps.

Colonnar sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. These columns and vertical sheets 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, as shown 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 column arrangement of the descriptions, and of the lithologic symbols, and 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 relative position.

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 columns of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically by a word "unconformity," printed in the "Time column.

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 its geographic features, soils, or other facts related to it.

J. W. POWELL.