The Geological Survey is making a geologic map of the United States, which is being issued in part, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

**The Topographic Map**

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

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

The nature in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is purely closed by a hooked sand bar. On each side of the valley the land rises to a terrace on the right a hill rises gradually, while from that on the left the ground sours steeply, forming a perpendicular cliff. Contoured with this profile is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may clear the manner in which contours delineate elevation, form, and grade.

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; that is, every ten feet above sea level, the contour at 250 feet lies all points of the surface that are 250 feet above sea level. Along the contour at 250 feet all points of the surface that are 250 feet above sea level are on exactly the same level; accordingly the contour at 450 feet surrounds it. In this illustration all the contours are numbered, and those for 500 feet are given, those for 400 feet being accounted for by being made heavier. Usually it is not desirable to number all the contours, and then the assigning of numbers is left to the discretion of them—any fifty one suffice, for the heights of others may be determined by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they show smoothly about smooth surfaces, recede into all treatment angles of rising of proper forms for the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and distribu- tories, and are essential for schools and homes and be useful as a map for local reference.

3. Contours show the approximate grade of any slope. The altitude or slope between two contours is equal to the difference in the elevations of these two nearly gentle slopes; but to rise a given height on a gentle slope one must go farther than on a steep slope, and the grade may be shown by the slope of lines on gentle slopes and near steep on ones.

For a flat or gently undulating country a small contour interval is useful; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain ranges, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, and 100, and 200 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire line its course is drawn unbroken, but if the channel is at a part of the watercourse, the streamline is broken and continues at the surface, the supposed underground course is shown by a broken line. A stream following a rock escarpment is shown in blue, whereas water are shown in blue, by appropriate conventional signs.

Conventional lines of works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Vegetation.—The area of the United States excluding Alaska and inland possessions is about 932,500,000 square miles. A map representing this area, drawn to the scale to which it would cover 3,025,000 square inches of paper, and to accommodate the map the paper would measure about 14 by 18 inches. Each square inch of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator is the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to 63,360" is expressed by the fraction 1/63,360.

These scales are used on the atlas sheets of the Geological Survey; the smallest is 1/63,360, the intermediate is 1/126,720, and the largest is 1/243,440. Each sheet on the scale of 1/63,360 covers approximately to 4 miles, 2 miles, and 1 mile on the ground to m inch on the map. On the scale of 1/126,720 the map surfaces of about 1 square mile of earth surface; on the scale 1/243,440 about 4 square miles; and on the scale 1/486,880 about 16 square miles. At the bottom of each sheet the scale is expressed in words—by a graduated line representing miles and parts of miles in English inches, by a similar line indicating distance in the metric system, and by a fraction.

**The Geologic Map**

The maps representing the geology show, by colors, the geologic formations. On the base map of every geographic base, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

**Kinds of Rocks**

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

**Igneous Rocks**—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, through the upper surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called intrusive rocks. Rocks formed above the surface that has been approximately parallel with the mass is called a dike; when it fills a large and irregular conduit formed by a dike the rock is called a sills. When the conduits of molten magnesium traversed stratified rocks they often fed off branches parallel to the bedding planes; the rock masses filling such fissures are called pipes, or sills when comparatively thin, and dikes when occupying larger channels produced by erosion. The pressure of the magma upward, and the movement of the liquid magma, cause the structure of the liquid magma to be changed and its volume to be reduced, and new structures appear. The structure and character of the joint and division planes along which the rocks split easily, and those planes may cross the strata at any angle. This structure is called cleavage. Sometimes grains of mica or other foliaceous minerals are developed with their limbs approximately parallel; in such cases the structure is said to be schistose, or characterized by schistosity.

As a rule, the oldest rocks are most altered, and those close to an igneous mass have escaped metamorphism, but to this rule there are many important exceptions.

**Sedimentary Rocks**—These are rocks composed of the materials of older rocks which have been detached by weathering from the surface of the earth and are transported, precipitated, concretions, cemented, agglomerated, and tuffs. Volcanic ejects may fall in bodies of water or may be carried into lakes or sea and form a sedimentary rock. Sedimentary rocks are those rocks which are composed of materials which have been carried to a different place and deposited.

The chief agent of transportation of rock debris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Sand is gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and slate. In colluvial and alluvial deposits, materials are carried by waving and wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-blown or colluvial sediments are the loess, which consist of very fine, acicular graticle of glacial deposits is till, a heterogeneous mixture of boulders and pebbles with clay or sand. Sedimentary rocks are usually of one kind of rock and are usually of the same kind and can be easily separated. These rocks are called sandstone. Rocks deposited in layers are said to be stratified. The surface of the earth is not fixed, so it seems to be; it very slowly rises or sinks, with reference to the sea, ever wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and vice versa, and then the land is occupied by such rocks.

Rocks exposed at the surface of the land are called land surface rocks; those that are gradually exposed by rivers to the ocean or other bodies of standing water, and are the first to be worked by man, are called surficial rocks, and the land bodies belong to the surficial class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

**Metamorphic Rocks**—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called metamorphic. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be removed, other substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock, and the term "metamorphism" is used to express a process of change involving these gradations.

**Geologic Formations**—In the use of geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process of burial pressure, movement, and chemical activity, their original structure may be entirely lost and new structures appear. Calcite, feldspar, quartz, micas and other minerals are transformed, along which the rocks split easily, and those planes may cross the strata at any angle. This structure is called cleavage. Sometimes grains of mica or other foliaceous minerals are developed with their limbs approximately parallel; in such cases the structure is said to be schistose, or characterized by schistosity.

As a rule, the oldest rocks are most altered, and those close to an igneous mass have escaped metamorphism, but to this rule there are many important exceptions.

For purposes of geologic mapping rocks of all the above classes are divided into families.

A sedimentary formation contains between its upper and lower limits either rocks of uniform character, which are continuously varied, or rocks of uniform character, as, for example, a rapid alternation of slate and limestone. When the passage from one kind of rocks to another is gradual it is sometimes called a metamorphic formation or of one geologic series or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more rock formations, the group or combination of rocks with such parts are called members, or by some other appropriate term, as beds.
DESCRIPTION OF THE RICO QUADRANGLE.

By Whitman Cross and J. E. Randome.

INTRODUCTION.

The Rico quadrangle is situated in southwestern Colorado, about 50 miles west of the Continental Divide, in the zone bordering the San Juan Mountains, almost at the head of the Dolores River. It is bounded by meridians 108° and 108° 12' west longitude and parallels 37° 30' and 37° 45' north latitude, embracing about 250 square miles.

GENERAL RELATION OF THE QUADRANGLE.

Relation to the plateau country.—The Rico quadrangle lies in the southwestern part of Colorado, which marks the eastern border of a very notable plateau surface which covers the greater part of the area between the Colorado River in Utah and the San Juan Mountains of Colorado. Below the gently undulating surface of this plateau many canyons have been cut by streams, one of the principal gorges being that of the Dolores River. Entering its canyon valley within the Rico quadrangle this stream flows with irregular course for about 18 miles in a southwesterly direction and then swings to a general north-northwesterly trend, which it maintains for over 100 miles to the Grand River.

The larger part of the plateau surface lying between the Dolores and Colorado rivers is called the Great Sage Plain, while its direct continuation eastward and toward the head of the Dolores is named the Dolores Plateau. This broad plain surface is due chiefly to a heavy sandstone, the Dakota (Cretaceous), and its sandstones are in part structural, in harmony with the slightly varying dips of the sandstone, and in part owing to remnants of the soft, thick shale formation normally overlying the sandstone. The Great Sage Plain of Utah has a general elevation of 6000 to 7000 feet above the sea. Eastward the slope of the plateau becomes slightly steeper, but it retains an altitude of over 5000 feet. Beyond this line it rises more gradually, and as the Dakota sandstone and other formations take part in the local structures of the Rico and La Plata Mountains, we are left to account for the continuous and variously directed slopes to the east.

Relation to the San Juan Mountains.—The southwestern front of the volcanic San Juan Mountains lies 6 to 8 miles northeast of the Rico quadrangle. The intervening space is characterized by irregular topography, with features due in part to the upwarping and erosion of various sedimentary formations about the ancient San Juan center of uplift and in part to large masses of intrusive igneous rocks. These intrusions are in character similar to those of the Rico Mountains.

The quadrangle is geologically related to the San Juan region chiefly is regarded to pre-Tertiary formations and structure and the Quaternary erosion of streams heading on the San Juan Flank.

Features of the Rico Mountains.—The small group of mountains in the northeastern section of the quadrangle is in large degree a local upfold of which begins a mile or two south of the quadrangle line. Between the Rico and La Plata Mountains the mass is cut off by a valley and does not reappear to the east side because of the upwarping of all formations on this general line, under the influence of the great mountain structure. Almost the entire surface of these mass or plateau remnants is covered by a forest growth of the white pine and aspen, the chief dominant species. The mass border southeast of Bear Creek is especially characterized by a magnificent growth of stately aspens. At lower levels, willows, cottonwood, and scrub oak become more and more prominent.

The Rico Mountains.—The summits of this compact and rather isolated group lie within an oval area about 7 miles in diameter from east to west and 3 miles from north to south. The peaks are nearly all included within the northwestern section of the Rico quadrangle, but a few lie east of the one hundred and eighth meridian, in the Engineer Mountain quadrangle.

The topographic map of the quadrangle shows the general character of the mountains as composed with the plateaus and not the long lateral ridges of the Dolores Valley. The special sheet exhibits the finer details of form and includes the peaks situated on the quadrangle line.

From these maps it may be seen that the Rico Mountains consist of a circle of high and rugged peaks, divided into two eroded basins by the Dolores Valley. There are twelve peaks, each exceeding 12,000 feet in elevation above sea level, and the northern crest connecting them rarely sinks below 11,500 feet on either side of the river. In passing through the group the Dolores river makes a few curving by the outer margin of the Dolores Valley. The whole river section is nearly 400 feet above the valley, and the stream is actively engaged in the work of erosion.

The characteristic forms of peaks and gulches of these mountains are shown to advantage in this folder. Fig. 1 in particular shows the details of form commonly prominent in the higher summits on the eastern side of the river. Timber line in the Rico Mountains lies between 11,500 and 12,000 feet, and its course may be traced in several of the Illustrations of the folder. The Dolores Valley.—The Dolores River has carved its valley through the heart of the Rico Mountains, and near its western boundary of the quadrangle it enters a canyon, cut far below the plateau level, in which it flows to its junction with the Grand River. The boundary of the main stream within the area are all, except Bear Creek, which leads a few miles to the south in the La Plata Mountains. The West Dolores Valley is nearly as large as the main fork, but lies wholly within the plateau region. The extreme head of the Dolores is at the northeast base of the Rico Mountains.

The canyons of the Dolores River, Lest Canyon, Stoner Creek, and the West Dolores are characterized of the drainage channels of the plateau country. The sides are steep and are modified by many minor scarps representing resistant sandstone strata.

GEOLOGICAL INVESTIGATION OF THE REGION.

The Hayden Survey.—The country adjacent to Rico was visited by geologists of the Hayden Survey in 1874 and 1876. In the former year P. M. Endlich examined the district to the east, the one hundred and eighth meridian, passing through Talcotope Mountain, being apparently the general western boundary of his field of work. In 1876 W. H. Holmes made a rapid reconnaissance over the plateau country to the west. The completed geology of the Rico uplift, coming on the border zone between the fields of different men working in different areas, did not receive adequate attention, and the Hayden map of this area is, therefore, quite unsatisfactory.

J. E. Forish and T. A. Richard.—The only geological explorations of the quadrangle since the time of the Hayden Survey have been connected with mining developments in the Rico Mountains. In the course of descriptions of some of the mineral properties near Rico there have been brief discussions of the geology of the mountain group. These discussions were for the most part found on observations near and in the mines of New Mill. In 1902 John B. Forish read a paper before the Colorado Scientific Society entitled "On the Ore Deposits of Newman Hill, near Rico, Colorado." In 1910 John B. Forish and a paper before the Colorado Scientific Society entitled "On the Ore Deposits of Newman Hill, near Rico, Colorado." In 1910 John B. Forish and A. A. Richert, then superintendent of the mines (Tenn. Am. Inst. Min. Eng., vol. 30, pp. 596-560). In this paper there are but few statements concerning the general geology. The strata about Rico are said to be fissile and to belong to the lower Car- boniferous, and the common igneous rock is called porphyry, and is concisely described by E. C. Hille. Richert refers to "a large dike of porphyry which cuts the valley north of Rico, "making a fault which breaks the continuity of the country on either side." It would appear that this occurrence must be the mass of whites with small flakes of hornblende porphyry; but the position and importance of the fault are not further indicated.

A detailed description of the Enterprise mine near Rico, was published in 1895 by T. A. Richard, then superintendent of the mines (Tenn. Am. Inst. Min. Eng., vol. 30, pp. 596-560). In this paper there are but few statements concerning the general geology. The strata about Rico are said to be fissile and to belong to the lower Carboniferous, and the common igneous rock is called porphyry, and is concisely described by E. C. Hille. Richert refers to "a large dike of porphyry which cuts the valley north of Rico, "making a fault which breaks the continuity of the country on either side." It would appear that this occurrence must be the mass of whites with small flakes of hornblende porphyry; but the position and importance of the fault are not further indicated.

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DESCRIPTIVE GEOLOGY.  
THE ROCK FORMATIONS.  
SEQUENTIALLY AND BEYONDICIDE ROCKS.  
ALGONKIN SYSTEM.  
Introductory statement.—The rocks which are described as Algongkin occupy a small area in the center of the Rice Mountains, where they have been exposed by the cutting of the Delvee Valley through the heart of the uplift. They comprise quartzites and quartzitic schists and are similar to the series of rocks exposed in the Uncompahgre Canyon on the north side of the San Juan Mountains and in the Needle Mountains on the south side of the San Juan. In the latter area they are represented on the Hayden map as "metamorphic Paleozoic." The quartzites of the Animas Canyon section through the Needle Mountains have been examined by Eames and Van Hise, who have assigned them to the Algongkin system. The correctness of this assignment is confirmed by recent work of the Geological Survey in the Needle Mountains and the discovery of Cambrian fossils in the lowest Paleozoic formation of that area, which rests unconformably on the quartzites and other pre-Cambrian rocks. In the Silver Creek Valley the particles of thin bedding and combing, and conglomeration of this ancient complex were called the Uncompahgre formation. The Uncompahgre quartzites and slates are underlain in the Needle Mountains by a thick conglomerate called the Vallecito formation. The Vallecito and the Uncompahgre together constitute the Needle Mountains group, according to the nomenclature proposed in the Needle Mountains fossiliferous formation.  
Character.—The Algongkin rocks, very imperfectly exposed at Rice, consists of small, locally quartzitic, quartzitic schists bearing small amounts of mica. The quartzites are found only in the valley of Silver Creek, in small upthrust blocks, and are not distinguishable in character from other quartzites, to be described later, which are supposed to be the visible thicknesses, and the stratigraphic attitude of the Algongkin rocks make it impossible to refer them to this thin Cambrian formation of this region. They are white or tinged with brown, with occasional red or rusty bands. They are composed almost entirely of quartz, occurring usually in small, eucoriaeomorphic particles, but sometimes in the form of pebbles less than an inch in diameter. The rock is completely indurated by the interstitial deposition of quartz, so that it is now glazy quartzite, very resistant to erosion. Distinct partings between the beds of quartzite are nowhere observable in present exposures. However, the bedding or stratification planes may frequently be made out by a study of the massive quartzites, where differences of grains are found or where cross-bedding is observable. Ripple-marked surfaces are also occasionally seen.  
OCCURRENCE.—There are six separate localities of quartzite in the valley of Silver Creek, and of these one, that below Ally Gilch, is certainly Algongkin. In the other five, another, on the opposite side of Silver Creek, is probably of that age; while the others have been assigned to the Cambrian. In the places first mentioned the quartizes have their greatest development. They are bounded on the east by a well-marked fault, shown toward the southwest they may be traced for a quarter of a mile along the hillside, on the slope of whose outcrops are to be seen the elevations of 9000 and 6000 feet, showing a continuous exposure at one place to a thickness of 350 feet, though from the structure it is probable that a greater thickness exists. The strike may be determined in this region and, while both are variable, the former is generally about N. 30° E. and the latter about N. 25° E. The beds are, however, much less distinct than in the Eocene formation, for they dip at an angle of 15° east. On the north, south, and west the boundaries of this mass of quartzite are not known, since they are covered by surface waters. The separation of the upper and lower portions of the rock is marked in the manner indicated on the map, while on the north it may connect under the north side of Silver Creek. 
Within the area just mentioned the rocks are very imperfectly exposed, except in the valley of Silver Creek, but these from and the data derived from tundras and prospects it is definitely known that the northern limit is along the Lower Animas fault, which joins the Aupa Mine. 
Character.—The remaining rocks of probable Algongkin age at Rice may be divided into two classes: those which have a more or less distinct foliated structure, not due to original bedding, but superimposed by metamorphism under stress, and those which show no such stratifiation and are sometimes made out in some cases by differences in the character of adjacent bands, and to this structure the foliation is generally, though not always, parallel. The direction of foliation does not vary greatly from east and west, and its position varies vertically whenever observed. 
The schists are dense bluish-gray rocks, the foliation being caused by the arrangement of the thin flakes of different minerals and is very noticeable to the unaided eye. A delicate luster is visible on the planes of easier fracture, but the schistosity is never highly developed and the rocks often break readily across the structure with almost conchoidal fracture. 
In a few places the rock has quite clearly the character of a mafic rock, apparently derived from a porphyry in which there were phanerocrystals of quartz and feldspar. There is a slight development of tourmaline in some rocks. 
Introducible into these schists, in general parallel to the foliation, are porphyry-like veins, frequently thin, dark dikes of a dark porphyry that are prominent on both sides of the river, but have not been referred to the Delvee, though with a reference to other rocks than the schist; hence they are supposed to be very old intrusions, independent of the Delvee system, which is the only formation sub-stenating by the matching of some of the dikes. Stout spires of hornblende are the only prominent crystals of the rock. There is also much secondary hornblende and epidote revealed by the microscope. The former subordinately feldsparitic composition is much crushed and altered that the original character can not be determined. 
Pyroclastic was probably predominant over orthoclase. 
Occurrence.—The Algongkin schists occur only in the Delvee Valley just above Rice in small upthrust fault blocks, and the structure about them is complex, as is shown by the relations of the schists to the Algongkin quartzites and of the latter to small areas of Paleozoic rocks. 
CAMPBELL (? ) SYSTEM.  
DECKRO QUARTZITES.  
Introductory statement.—The lower member of the Cambrian section described in this paper comprises the Deckro Quartzites. The formation is a quartzite which was grouped with the overlying limestones in the Rice report, both being referred to the Delvee, though with a reservation as to the quartzite, since it was recognized that that formation might be much older than the limestones. Recent investigations in the quartzites laying east of the Rice have shown not only that the quartzites are probably of Superiorian (Upper Cambrian) age, but that another this formation recognizing occurrence occurs among the quartzites and the Delvee limestones. This intermediate formation consists, as known in the Rockport basin, of broken, bouldery limestone and conglomerate shales with varying amounts of thin quartzite, the whole less than 100 feet in thick- ness. The upper and major part of the formation is massive limestone, either in one bed or with such thin intercalated shales that the limestones are continuous across the whole basin to rest erosion, and in the lower part limestone becomes a lenticular and to thus cause gaps, benches, and prominent cliffs which are characteristic topographic forms, is always noticeable. Below the more massive portion a third or less of the section is made of well-bedded limestones with distinct shaly layers and, rarely, thin quartzites, between them. Some of the lower layers have a wavy bedding, some are arenaceous or earthy, and large chalk concretions, free from organic matter occur at a horizon near the base. 
The lowest stratum is characterized usually by crinoid stems and rarely a cup couple. 
The characteristic feature is dense, compact, and massive, but of the upper layer are coarse crystalline. In general, the rock is nearly white, but with a cloudy, veined, and colorless rock in the Desert City area. Some of the lower beds are strongly yellow and these are commonly more or less sandy. The contrast with the dark gray, dense limestones of the Hermosan is marked, layers of such character occurring only near the base of the Ozyme. The horizon of the Ozyme is litho- 
Finnas and correlations.—The Deckro invertebrates occur near the base to a horizon in which may not be far below the top of the upper, massive, limes. The horizon of the Ozyme occurs in this upper section, but many of them range to within a few feet of the base. 
The Deckro beds have been found at several localities in the Animas Valley in coarse crystalline beds near the top of the formation. 
Fossils have not been found at Rice, but have been obtained at Ozyme and at several localities on the southern slopes of the San Juan, including that where Emsell first found a characteristic Deckro species, and at a horizon near the base. 
the invertebrate fauna of the Deckro has been studied by P. H. Girty and compared with similar faunas hitherto collected in Colorado, but not recognized as distinct from the forms of the Mississippi. It is closely related to the Deckro of Iowa. Emsell on the Eocene fauna from the Elk Mountains, at Glenwood Springs on Grand River near the head of White River, and in the Coster Mountains on Chaffee County. 
Ozyme quartzites, and the correlation of the sections in these localities with that of the San Juan region can not be made, however, until further examinations have been carried out. Concerning the fauna the Mr. G. Girty writes: 
In general the Deckro fauna of the Ozyme belongs to late middle or, more probably, to upper Devonian time. It is but distantly related to the Devonian faunas of New York, and its relation with those of the Mississippi Valley, or even with other known western Devonian faunas, is not close. It shows many points of the Appalachian fauna described by Whittaker, and is somewhat strikingly similar to the Devonian fauna of the Ohio Valley. 
The following named species are particularly characteristic of the Devonian portion of the Ozyme fauna: 

**Schizocanthes Moschellatana** Camaroceras Endlichii. 
**Camaroceras Chaffeei** Endlichii. 
**Cordylophorella Moschellatana**. 
**Algida Mesosoma**. 
**Pseudaldelphia**. 
**Spinter lampmanii** var. Animiae. 

As to the Mississippian fauna of the Ozyme formation Mr. Girty makes the following statement: 

The fauna which at one time occupied the higher beds of the Ozyme limestones is very different from the above specimen. 

**?**
The Formation of the Río Misisippian fossils is abundant. The region stretches from the eastern edge of the floodplain to the western boundary of the Coosa River floodplain. The formation is characterized by its diverse marine invertebrates, including brachiopods, bivalves, and gastropods. The Río Misisippian rocks are also notable for their excellent fossil preservation, which allows for detailed study of the paleoecology of the area.

The Río Misisippian Formation is divided into two members: the Río Misisippian and the Coosa River Formation. The Río Misisippian member is the lower unit and consists of a thick sequence of shallow marine sediments. The Coosa River Formation is the upper unit and is characterized by more marine and deltaic sediments.

The Río Misisippian Formation is significant for its fossil record. The abundance of marine invertebrates, including brachiopods, bivalves, and gastropods, provides a window into the paleoecology of the area. The Río Misisippian rocks are also notable for their excellent fossil preservation, which allows for detailed study of the paleoecology of the area.

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The corner specimens are usually found in bedded and occur in massive beds from 2 to 30 in thickness. Some of the corner specimens are of very much lighter color than the matrix of the formation, which is usually somewhat lustrous and pass softly into sandy shales. The shales, aside from the sandy varieties, are of two kinds—the fine-grained, generally red, sandy beds, similar to those of the Cutler, and the equally fine-grained, laminated clay shales of a greenish color.

Interspersed with the sandstones and shales, which are for the most part very uncommon throughout, there are some beds of light-colored limestones, some as clary, gray, sometimes nodular bands associated with the sandy shales, and others as sandy limestones of a red color, in strata from 6 inches to 2 feet in thickness. The latter, and a 6-inch layer of limestone which was taken at the upper limit of the formation in Scott Creek, are very fossiliferous. The sandstone beds have a characteristic appearance wherever they are found, since the fossils are preserved in white calcite, in sharp contrast to the red matrix of osseous sand. They are found in the lower third of the formation, and while some of them are of local development and may be seen to grade both vertically and horizontally into the red beds, others are usually associated, at least one bed is known to be present in the region, and its equivalent has been recognized in the Animas Valley where its horizon has been studied. This fossiliferous sandstone bed has thus been diagnostic of the Dolores formation, and is the key bed in the study of the stratigraphy of the region, since it occurs within a few feet of shales which contain cephalopods and other Archaean fossils. At this point, the position varies little from 30 feet above the Uppermost of the Unconformity from which it is separated by green micaceous shales containing shell fragments and crinoid stems, and is thus a reliable guide in defining the two formations. The formation is without any definitive limits at this point, since the rocks which follow immediately above the highest known fossil-bearing beds are similar in every respect to the strata of the lower series; nor is it possible to apply the change in color or a criterion, except in a very general way; so that it has been found necessary to assume the thickness of the formation as equal to the greatest known thickness near the base of the upper member of fossiliferous stratum.

In Scott Creek the thickness on this basis would be 237 feet; on the north side of Silver Creek, near Uncle Ned Dale, it would be about the same; but on the opposite slope of the Bigger Haly Basin it is more than 500 feet. In drawing this upper boundary on the map, the formation has been represented as about 500 feet in thickness.

The measured section taken in the lower part of Scott Creek, which is given in the next column, shows the thick and thin beds of the formation, which will be brought out in the following discussion.

Immediately below the lowest fossiliferous limestones there are 25 feet of micaceous clays, carrying a few shell fragments and representing the topmost beds of the Hermosa formation.

Correlation.—Pernian fossils, consisting for the most part of plant remains, were reported from various parts of Colorado by members of the Hayash Geological Survey (Report on the geology of the Grand River division, A. C. Frels; U. S. Geol. and Terr. Surv. for 1875, p. 74), but the collections and the analysis of the strata have so far not been completed as to establish the presence of rocks of this age in any bed of the San Juan. The highest beds of the Hermosa formation are not well marked, but in the bed of the Colorado River near the north end of the basin of Dolores, the upper beds are nowhere obscure, and the thin beds of limestones which are thick in the north end of the basin, especially near the confluence with the Dolores, are often 18 inches thick. The limestones are described as thin, gray, and a little lustrous, with occasional impure limestones or marls. The name of the bed is derived from Cutler Creek, a tributary of the Uncompahgre River in Colorad. Overly, and it was first used as a species name in the Silverton area of the Colorado region. The principal feature of the Cutler formation are, on one hand, the heavy grits and conglomerates, and on the other, some very coarse, gravelly sandstone, which grades into sandier shales and impure limestones of nodular, concholeural or irregular forms. The grits and conglomerates occur in massive beds reaching a maximum thickness of 60 feet. Their alternation with fine-grained and softer beds causes an enormous succession of benches and ledges on numerous lateral ridges of the Dolores Valley. The grits are mostly of red, pinkish-feldspar and yellow quartz, and they are either gray in color or have a much lighter pink tone than the lower part of the formation. Pebbles of various sizes and shapes are generally grouped by the grit layers, causing transitions to conglomerates, and the gravel mass is typically composed of the latter strata.

The pebbles of the conglomerate average but a few inches in diameter, but are occasionally more than a foot in diameter. The cuticles of the Cutler conglomerates of the Dolores Valley, but such materials are much more abundant in the conglomerates of the Unconformity.

A calcareous cement is common in all the cutters, but not infrequently certain minor strata grade into sandy limestones which have a peculiar conchoidal fracture. There are local occurrences of thin red or grayish limestones, which appear to grade into the Cutler conglomerates, but one might look rather like conglomerate on weathered faces. In some cases there is an apparent gradation from sandstone into conglomerate, with many narrow fragments in a stringy mass of sediment. These appear to be interstratified conglomerates.

Nearly all the fossiliferous strata are deep red in color and in each case contain a ferruginous pigment in minute specks. The color is never so bright red in the Cutler bed as in the overlying Dolores formation. The grays and conglomerates are grayish or reddish, and in places, clayey or sandy, with a few more or less distinct nodules of red or grayish or grayish brown in color. All the known fossils of the Dolores bed also occur in these conglomerates.

The limestone of the conglomerate is usually very fine-grained and seldom resembles the limestone of the Dolores formation. The lower portion consists of a combination of rather thin-bedded sandstones, sandy shales, and limnic conglomerates, in the aggregate some 250 feet in thickness. This series of beds is characterized by the limestone conglomerates and by the fact that the strata are more or less of ferruginous redish or grayish gray or distinctly red in color. All the known fossils of the Dolores bed also occur in these beds.

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The thickness of the Dolores formation varies greatly throughout the Rico and adjacent quadrangle. This is chiefly due to the pre-La Plata erosion. About the La Plata Mountains the formation reaches nearly 800 feet in thickness. Thence northward it becomes much thinner, being about 400 feet near the mouth of the Rio Grande, locally but 30 feet on the San Miguel River, near Ouray about 50 feet, and still furthernorth diminishing entirely.

Description.—As the geologic map clearly shows, the Dolores is one of the most widely distributed and prominent members of the quadrangle. The brilliant cliffs of the upper massive sandstones are striking features of both the Dolores Valley and its western bench. As the strata rise toward the Rico Mountains they are less prominent, but many striking cliff exposures exhibit the characteristic varicolored color may be seen.

The lower division, with its fossiliferous lime-stone conglomerates, is well exposed in many localities and its general gray-green color often causes it to be conspicuous. The railroad cuttings from the mouth of Bear Creek westward for several miles exhibit this section of the formation very well.

Age and correlation.—The Dolores formation is regarded by paleontologists as of Triassic age, this determination being based on the scanty, yet widely distributed, ammonite, trilobite, and plant remains obtained from it. The limestone conglomerates usually contain fragmentary bones and fairly well-preserved crinoids and the remains of various Carboniferous forms. The trilobites and crinoids are not so characteristic as some still exist near the base of the section. The sandstone occurs in beds reaching 30 to 40 feet in thickness. They are separated by clay shales which are usually carbonaceous and as a rule carry thin seams of coal. These shaly members are strongly developed near the middle and again near the top of the formation. They contain abundant inelastic plant remains.

The sands from the shaly layers of the Dakota have been mined on the west bank of the Dolores River, just north of the Rico quadrangle. It is known to occur at several places in the western part of the quadrangle and also in the vicinity of Last Canyon, and it seems probable that one or more thin coal seams are present wherever the formation is represented on the map. This coal is not comparable in quality with the excellent seams of the Mancos formation and can not be of much economic value except in the plateau country remote from railroads.

Dakota sandstone is, as a rule, much more highly indurated than the La Plata or Mesa Verde sandstones. It therefore resists erosion better, so that they occur in strips of country that cut below in the plateau region. This formation is the floor of the plateau over hundreds of miles.

The Dakota sandstone is seldom well exposed in its entire thickness in the Rico quadrangle. The sandstone is the thinnest of all the exposed sections. It is assumed that approximately 50 feet of the formation is missing from the mesa west of Bear Creek and north of the Dolores River—but that erosion has not cleared away the Mancos shales from above it, but has also removed the upper part of the Dakota, which is less resistant than the lower portion on account of the presence in it of many thin shale layers.

Mancos Shale

Name and description.—The body of shale which lies above the Dakota sandstone was named the "Mancos shale" in the Telluride field on account of its characteristic development in the Mancos Valley, especially about the town of Mancos. In the Telluride quadrangle the formation is present as a succession of dark clay shales nearly 2000 feet thick. These shales are of uniform thickness, without any persistent lithologic or paleontologic horizon which can be used as a guide to subdivision. The shales are characteristically black in color, and are nearly always thin, sandy. Thin carbonaceous layers become interbedded in places and are often rich in fossils.
The principal deposits of olivine tufts have been outlined on the map, by references to which distribution and migration may be seen.

— Exposition statement. — By far the greater number of the igneous rocks occurring in the Rio Grande quadrangle are directly connected with the eroding center in the Rio Micos. A very few mesas near the southern border belong to the La Plata center, and it may be assumed that the small dikes at some distance from either mountain group are genetically related to one or the other of the centers.

The intrusive sheets and dikes occurring in the Rio Micos are nearly all of one chemical and mineralogical type, but present many minor textural variations, which were not caused by slight local differences in the conditions attending their consolidation. These modifications do not obscure the similarity in composition when the rocks are studied under the microscope, but some mass is too fine grained for the naked eye to recognize their constitution with certainty, and the names assigned to them cannot be regarded as characteristic of the various rocks.

The rock of the larger sheets and of many dikes is a very distinct porphyry of general light-gray color, which is distinguished from others by characteristic phenocrysts and exsolutions.

The gray and homogenous-aquamarine groundmass consists of orthoclase and quartz.

The most striking variation in texture noticeable in these rocks arises from the development of the plagioclase phenocrysts. These are more abundant than hornblende and, as a rule, are larger. But they may be nearly uniform in size or present a gradation from the largest to the smallest, each size being distinguishable by the naked eye. In the sheet crossing the Dolores Valley at Montezuma, for example, the plagioclase crystals are uniformly about 2 millimeters in diameter wherever that part of the mass was examined. More commonly there are numerous crystals of 5 millimeters or more, though the average remains in the neighborhood of 2 millimeters.
Two long dolies of the Rico quadrangle belong to a variety of monzonite porphyry, the common form of the Rico Mountains. One of these dolies crosses the Dolores River a short distance south of the Rico. The other dikes of similar rock cross the head of Priest Gulch, and from its course would seem to be connected with the Rico center. These two porphyries contain a larger amount of feldspar than the prevalent porphyry of the Rico Mountains, and the dark silicate is probably of the same type. The cross sections of the granite are octagonal, but no traces of its scattered substance have been found. The feldspar phenocrysts are all plagioclase and the feldic groundmass, mainly alkali feldspar, the two kinds being nearly equal in amount in the rock as a whole. It is supposed that the groundmass feldspar is ortho-

clide rich in soda, from the soda-like aspect of the particles and the general resemblance of these rocks to certain porphyries of the La Plata Moun-
tains which were called syenite-porphyry in the La Plata folio. Quartz occurs but rarely in the
groundmass.

The mass of the large stock west of Rico is a gray granular rock containing orthoclase and plagioclase in about equal amounts, carrying a little quartz and having a variable deve-

lopment of augite, hornblende, and biotite. The feldspar phenocrysts are 1/8-1/2 inch in diameter and the groundmass is a nearly colorless mineral, ordi-
narily too fine grained for recognition. The altered granite in which it is found may be fine or coarse grained. In some places the rock has become largely a porous quartzite. The rocks of the large feldspar crystals is sioahn completely filled by the alteration product, which usually appears as an aggregate of rume plates, a def-

inite crystal outline being, however, rare. These plates are rough crystals of albite, the basal plane of which has been in contact with the feldspar phenocrysts. At several places the freshly fractured rock was found to exhibit a very distinct yellow color in the microscope representing feldspar phenocrysts, the color being due to native sulphur in minute round crystalline particles.

The more massive rock found in many places consists of a coarse-grained aggregate of irregular, rude tablets with kaolin filling the interstices. The color of the feldspar phenocrysts of this rock ensures the groundmass, the material being unrecognizable by the naked eye. The rock of the Rico Mountains in chemical constitution, augite is much more abundant in this than hornblende, which is the characteristic dark silicate of the porphyries. Mon-

zonites very similar to that at Rico occur in large
textures in the Tellerite and La Plata quadrangles and have been fully described in the published folios.

CALICO PEAK PORPHYRY.

A rock of unusual character occurs in dike form on the north slope and elsewhere in the vicinity of Calico Peak, and in a sheet-like body in Dolores sandstone at the head of Priest Gulch. This rock is a porphyry of most marked appearance, charac-
terized by large orthoclase phenocrysts in consid-
erable abundance, some of them exceeding an inch in length. Associated with these prominent crys-
tals are small, cloudy bluish and green, or olivine phenocrysts and what is supposed to be altered albite, but the rock is mostly fresh. The dark rock is distinguish-
ble in some places through the pinkish color of the orthoclase, but this is entirely lacking in many areas. Even in the rock of moderate size the dark phenocrysts are not easy to discriminate, the term which would have been applied to these masses a few years ago. While this gran-

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Newman Hill porphyry sheet, and takes no account of other probable intrusive sheets. The base of the La Plata on this estimate must have been at about the altitude of 3,100 feet or more, and at least 1,500 feet above the highest point of the Rio district. It is plain that none of this elevation may be due to faulting, but it will be seen that the map indicates that the uplift by dislocation is mainly north of the line of section A-A.

The amount of local dislocation which is thus indicated may be seen by comparing the position of the La Plata in the vicinity. About 5 miles north of Risco the base of this formation crosses the Dolores River at an elevation of 9,000 feet, showing a fall from the restored position over 1,900 feet, or nearly 800 feet per mile, independent of the influence of the porphyry sheet. Beyond this cutoff the northwest dips are continued for only a short distance, so that here we have the full measure of the local dislocation in this direction. In other directions the fall per mile is less, but the dips are continued for a greater distance.

Thus from the southwestern to the eastern part of the La Plata, the average depression or dip slope varies from 400 to 600 feet per mile of a distance of 5 to 8 miles, beyond which it gradually lessens as the distance from the center increases. The diminished dips continue for many miles toward the plateau region. Toward the south they fall at the rate of about 200 feet per mile, and are met by the structure of the La Plata Mountains at a distance of about 7 miles. Also to the southeast, though the La Plata is missing, the lower strata fall at a rate of 300 feet per mile for about 8 miles where the local structure is completely neutralized by the contrary dips away from the Needle Mountains. Four miles to the east of the La Plata is 1,700 feet lower than over the top of the dome and dips to the northeast, in which direction it continues to fall for several miles.

The attitude which the formations would now exhibit along the line of the Dolores Valley were it not for the Risco dome may be easily seen from the map, where the mesa and plateau occur in nearly the same horizon. In the southwest corner of the former, only 6 miles northeast of Risco, the Dolores flows in a canyon whose rim rock is the Dakota (Cretaceous) sandstone in almost horizontal position—the floor of the Dolores Plateau over large areas. As the valley of the Dolores leaves the Terrell quadrangle the formations rise rapidly under the influence of the Risco uplift, but at the mouth of Bear Creek, 12 miles below Risco, the stream is again coursing in a typical manner of the plateau country, the Dakota-sandstone members are very much opposed by the considerations connected with the intrusion of the igneous rocks. From the generally accepted theories in regard to the relations of the igneous intrusion to the Dakota character to the dome uplift it is necessary to assume that the porphyry sheets of Risco are contemporaneous with or later than the principal uplift. But these igneous rocks are cut by all faults observed to come in contact with them. No single instance was found of a porphyry dike ascending on a fault face.

Further, the Dakota sandstone is traversed by many small and branching fractures. It is therefore necessary to disconnect the fault phenomena of this region from the primary dome dislocation, as is possible, that some unidentifiable portion of the formation accompanied the faulting.

The displacement of the minor faults from common fracture faces to zones of shearing or brecciation many feet in width. Extensive brecciation is well shown in the prominent portions of the La Plata and in the veins of the Calumet, Zulu Chief, and several tunnels near Risco; in the "great veins" of the northern part of C. H. C. Hill; and in the boundary area of the Agalkin quadrangle in Silver Creek. Sheeting is also seen in most of these localities.

The distribution of the main faults is shown by the map. The general dislocations are near the center of the dome, but a large number of secondary fractures occur in the circle of peaks about it. A glance at the map will show that there is no parallelism entirely in these major faults of this formation, so far as they are exhibited in surface exposures, are of minor importance and could certainly in no single section aggregate more than 300 feet.

The Dolores and Cutler formations seem to have presented especially favorable conditions for subaqueous and brecciated intrusions; and these are localized, with respect to the dome, on the eastern and western sides of the basin in which they occur. The nature of the beds which they contain is not identical with the porphyry sheet, and it may be questioned whether any of the intrusive phenomena of the La Plata sandstone at the time of uplift. The Blackhawk and Nellie Bly faults are the principal ones, but the horizon of the La Plata sandstone must have been still measurable by hundreds of feet. But if the writer, for the time being, places the horizon of the Dolores River fault at the time of uplift, the displacement in a direction of several thousand feet cannot be ignored in the interpretation of the fault. The Blackhawk and Nellie Bly faults are the principal ones, but the horizon of the La Plata sandstone must have been still measurable by hundreds of feet. But if the writer, for the time being, places the horizon of the Dolores River fault at the time of uplift, the displacement in a direction of several thousand feet cannot be ignored in the interpretation of the fault. The Blackhawk and Nellie Bly faults are the principal ones, but the horizon of the La Plata sandstone must have been still measurable by hundreds of feet. But if the writer, for the time being, places the horizon of the Dolores River fault at the time of uplift, the displacement in a direction of several thousand feet cannot be ignored in the interpretation of the fault. The Blackhawk and Nellie Bly faults are the principal ones, but the horizon of the La Plata sandstone must have been still measurable by hundreds of feet. But if the writer, for the time being, places the horizon of the Dolores River fault at the time of uplift, the displacement in a direction of several thousand feet cannot be ignored in the interpretation of the fault.
times the preservation of the mountains as regions of high topographic relief is due to the presence of igneous rocks which have been more resistant to erosion than the sedimentary rocks. The discrete units, which are the uplifts in the range, are called intrusions. The intrusions are in the form of stocks, dikes, and sheets. To the latter, which may in some cases have a thickness of a few feet, is added the type known as laccoliths, a certain amount of the observed deformation of the stratified rocks is certainly due. In the La Plata Mountains the most of the intruded material of this matter shown in the horizons exposed is comparable to the deformations which they have inflicted on and about those that affect the lower formations, which are covered and therefore beyond observation; so that the very process of intrusion should bear the same proportion to the sedimentary rocks as in the observed section, the dominion should be accounted for without additional uplift. At Rico the structure and makeup of the dome is much better exhibited, and though the theory that the observed structure might be due to a large boudin lying between the Algonkian and Pahoa roc rocks was at one time entertained as a working hypothesis, it is now generally agreed that a mass of igneous rock does not exist, and that the amount of deformation which the uppermost strata of the region underwent was of several times in excess of the strain. The possible parts of the cuts are to be found in several places, one on the slope of White Mountain being shown in the picture. The presence of a thin listric conglomerate of the fissifolium section of the Dolores very near the summit of Blackhawk shows the projected horizon of the La Plata sandstone to be but a few hundred feet above that mountain.

The light reddish color is not self-evident in this illustration, yet the magnitude of the displacement on the Blackhawk fault is really shown, for the prominent limestones band of the Dolores Mountain slope is dropped on that fault to a level too low to permit its appearing within the field of view on the other side of Alyce Gap.

The finds of this area are clearly shown in many places by their dislocation of porphyry domes, but the grayish or tumbled slopes seen in fig. 1 often hinder a connected tracing out of some of them. The splitting of the Blackhawk fault into a number of different displacements is plainly visible on the slopes of Blackhawk Peak. It may be seen from fig. 1 how well the occurrence illustrates the peculiar dislocation of White Mountain and the narrow divide at the head of Deadwood Gulch. There are natural gaps in the slopes which affords several hundred feet high, shown in fig. 1. This mass extends around the head of Silver Creek, covering a large area, and its intrusive parts by slight cutting out almost in two by the head of Iron Dike. Here occurs the large stock of granular rock, quartz-mica-schist, which appears to be the most important intrusive formation, if not the largest, of the Rico center. The contacts of this stock are not well shown at any point, mainly on account of the obscurity of the surface. The stock has left a very clear record of the topography, which has resulted in talus and broken-rock piles, where larger landforms have not taken place.

The metamorphosed formation of the dolerite rocks on either side of the main dome on Darling Ridge is everywhere evidence of the proximity of the contact. Although the monzodiorite body is large and such massive rocks usually cause rugged topography, such is not here the case. This fact is probably due to the stranded condition of the stock, leading to rapid destruction of prominences by frosts. The large blocks of small and large dolerite spires and spurs, situated on the north side of Darling Ridge, are principally separated by masses of felsic tonalite and hypidiomorphic gneiss, the spires rising up from the flat. The assignment of these features to the landslips is the same as the main dome.

The summit area of the mountain is characterized by the characteristic features of the bouldery, lichen-covered slopes of the upper Hermosa, which cross the slope of Dolores Mountain seen in the central part of the view, and by many lines in the higher summits, due to stratification or to interrelated porphyry intrusions. The higher portions of all these peaks consist of the red Cutler and Dolores strata with sharply con- trasting grayish porphyry rocks. The rocks of the parts of the Cutler are to be found in several places, one on the slope of White Mountain being shown in the figure. The presence of a thin listnic conglomerate of the fissifolium section of the Dolores very near the summit of Blackhawk shows the projected horizon of the La Plata sandstone to be but a few hundred feet above that mountain.

The upper portion of the area shown is not self-evident in this illustration, yet the magnitude of the displacement on the Blackhawk fault is really shown, for the prominent limestones band of the Dolores Mountain slope is dropped on that fault to a level too low to permit its appearing within the field of view on the other side of Alyce Gap.

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The metamorphosed formation of the dolerite rocks on either side of the main dome on Darling Ridge is everywhere evidence of the proximity of the contact. Although the monzodiorite body is large and such massive rocks usually cause rugged topography, such is not here the case. This fact is probably due to the stranded condition of the stock, leading to rapid destruction of prominences by frosts. The large blocks of small and large dolerite spires and spurs, situated on the north side of Darling Ridge, are principally separated by masses of felsic tonalite and hypidiomorphic gneiss, the spires rising up from the flat. The assignment of these features to the landslips is the same as the main dome.

The summit area of the mountain is characterized by the characteristic features of the bouldery, lichen-covered slopes of the upper Hermosa, which cross the slope of Dolores Mountain seen in the central part of the view, and by many lines in the higher summits, due to stratification or to interrelated porphyry intrusions. The higher portions of all these peaks consist of the red Cutler and Dolores strata with sharply con- trasting grayish porphyry rocks. The rocks of the parts of the Cutler are to be found in several places, one on the slope of White Mountain being shown in the figure. The presence of a thin listnic conglomerate of the fissifolium section of the Dolores very near the summit of Blackhawk shows the projected horizon of the La Plata sandstone to be but a few hundred feet above that mountain.

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of the Horsethief Gulch is concealed by landslide debris. This is all the more striking when compared with the cliff exposures of Sundance Mountain. At the mouth of this gulch, however, there are so many places so shattered by important fractures running in all directions and the blocks bounded by these fractures are so plainly dislocated superficially that the whole mass is considered as broken and not strictly in place. The best illustration of the shattering is at the most southerly point of the Iron Gulch. By a glance at the map it will be seen that there are here a number of sharp pinnacles and on the map itself these two contours have been given. But a map of this scale fails to show the number of these knobs and the hollows, curving ravines, and irregular depressions between them, belonging to no drainage system.

The rock of the knobs is often fresh, but much shattered, and the valleys between are rounded by the gravel of disintegration washed into them. This topographic detail, though on the top of the ridge, is to be sought by careful study of landslide slopes. Below these pinnacles on the slope to Horse Creek are some other knobs of importance, whose masses are large and landable, and needlessly keeps nearly all the way to the creek bed.

Excised from the principal area of monoclinal, along the crest of the ridge, the primary boundaries of the rock formations are more or less clearly exposed, but from the crest to the bowls from Horse Creek the surface is a jumble of landslide blocks, large or small, intact or in process of dislocation, and geologic boundaries showing the original relations can not be traced. The general topography of this ridge is seen in fig. 3. The main feature is the great number of trenches, most frequently parallel to the contours, or nearly so, yet often running diagonally across the slope. They are as a rule not persistent for long in the field, but break off into some other trench or smaller channel.

A few of these lines are ravines of importance, shown by the maps, and at several places they run up or cut across the crest of the ridge.

Outside of the trenches are mounds, knolls, furrow-like ridges, or benches, in these are not infrequent landslide blocks by which various dip and strike lines and striations and the shattered conditions of the rocks add to the evidence of the landslide. No separation of flume channels on the south side of Horse Gulch between the river and the ravine opposite Simonel Hill.

It is probable that in some cases, especially on the higher slopes, the dislocation of slide blocks is not very great, but it is sufficient to make correlation of different出crop lines by which various flume lines and striation and the shattered conditions of the rocks add to the evidence of the landslide. No separation of flume channels on the north side of Horse Gulch between the river and the ravine opposite Simonel Hill.

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apparently splits into two or more small sheets before crossing the river, and many irregularities may well be assumed to exist.

The lower body is in the main of lacustrine character is further indicated by the limited exposure of its base in the workings of the South Park mine. Several small dikes or sheets of porphyry have been encountered in the mines of Newman Hill.

**Geological History.**

**Pre-Tertiary Events.**

**Introduction.**—The visible record of pre-Tertiary events in the geologic development of this area is closely associated with the structure and stratigraphic relations. From the dissection of the formations already given it appears that the section is merely like that much better exposed, in its lower portions at least, in the Animas Valley. No marked local characteristic has been observed in the Rico formations of pre-Tertiary age, so that the course of events here can only be assumed to have been that of the surrounding province, an outline of which has been presented in the Telluride and Silverton folios.

For the present folio it is considered sufficient to refer very briefly to the history preceding the continental uplift of the whole sedimentary section, in post-Laramian time.

**Post-Paleozoic.**—From the study of the Needle Mountains and the Animas Canyon sections it appears that the oldest rocks of this region are certain gneiss which are probably of Archean age. The younger series of rocks consists largely of igneous material, greatly metamorphosed and associated with various sediments. Following the accumulation of this complex came a long period of sedimentation during which the Uncompahgre gneiss, sandstones, and shales were deposited, in marked unconformity with the structure of older formations.

While the sequence of events is not wholly clear, it seems probable that great folding, faulting, and metamorphism have affected some formations. Other formations are tectonic of the Rico-Red Rocks group which appears to have been a general area of southwestern Colorado. A long-continued oscillatory movement of the earth's crust caused frequent recurrence of conditions favorable to the deposition of limestones, shales, and sandstones, forming the complex called the Hermon formation. Without visible break the Hermon beds grade into those of the Rico (Permo-Pennsylvanian) and those into the overlying Cutler and red beds, here assigned to the Permian.

The character of the Cutler formation is in general much like that of the lower portion of the Rico, and is often called the Red Beds. It is at this point that the graphic break separates them from strata containing a Pennsylvanian fauna. The fact that a break is now known to exist above it seems to be imposed on the assumption that the Paleozoic section of the San Juan region is complete. There may have been deposition of Pennsylvanian age which is now entirely absent, owing to the pre-Dolomite erosion.

**Dolomite uplift.**—The angular unconformity at the base of the Dolomite and older formations testifies to important uplift affecting the entire known plateau. The regional geologic extent of this uplift remains to be determined. The Cutler beds were sharply folded in the Animas district, but appear to have survived almost unaltered by the erosion and have been cut by the Dolomite and the La Plata formations. Similar relations are known elsewhere in Colorado.

The epoch of uplift and consequent erosion discussion was followed by the deposition of the fossiliferous Dolomite series, but until the horizon within the Triassic system represented by these beds has been determined it is premature to assign the orogenic movement to late Paleozoic rather than to early Mesozoic time.

**Mesozoic History.**—It seems probable that the Dolomite formation of Triassic age is to be found in the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic rocks are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to the west, Triassic strata are overlain by the Triassic strata, and in the La Plata Valley, on the northern side of the San Juan the La Plata transects the edges of older sediments and in the Animas district it is possible, on the other hand, that the Triassic formation is of Mesozoic age. In the upper Dolomite Valley, in the San Miguel to the east and the Animas to

**Tertiary Period.**

No surface rocks of the Tertiary period now exist in the Rico quadrangle, but it is necessary to follow the history of the region from the age which covered the area, in order to discuss intelligently the history of the Rico Mountains.

** Accumulation of the Telluride Conglomerate.**

When the pre-Dolomite produced by erosion followed the deposition of the Rico formation had reached a certain stage of development the local conditions changed, so that a great amount of debris from the cutting of the Rico mountains was deposited upon it as a conglomerate formation. This formation, originally called the San Miguel Conglomerate, and the Telluride, acquired a rapidly increasing thickness westward from its border in the Silverton quadrangle and eastward on its border it is 50 feet or less thick and is a coarse conglomerate.

In Mount Wilson, a few miles north of Rico, it is more than 2000 feet thick and consists of fine conglomerate, sandstone, and thin beds of silts and clays being entirely exposed for the transition from the coarse conglomerate to the fine sandstone.

While much of the Telluride formation is well stratified and apparently of subaqueous origin, it seems possible that it had been of fluvial origin. In any case it probably that the conglomerate was deposited upon the Rico area with a texture and thickness corresponding to that exhibited in the San Miguel Mountains.

No fossils have been found in the Telluride formation, hence its exact age is unknown. Its relations to the whole of the Rico formation and the underlying Agate Creek formation of Triassic age is the problem of the present discussion. A full discussion of this question is given in the Telluride and Silverton folios.

**San Juan volcanic eruptions.**

The volcanic complex of the San Juan region is known to be the result of outpourings of various kinds and with various products, extending through Tertiary time. The earliest eruptions must have followed the deposition of the Telluride conglomerate and the Rico formations, extending through Tertiary time, and last until about the close of the Eocene period.

**Coneoconala formation.**—The oldest of these eruptions is the Coneoconala formation of the San Juan region, which is very similar to rocks of the Rico region. The deposits of this formation are widely distributed in the mountains and in the mountains of the Rico-Red Rocks group, where they are associated with the Rico volcanic rocks, and are, therefore, the equivalent of the Rico dolomite.

**Sedimentary facies of the Rico and La Plata mountains.**

While no surface volcanic rocks are preserved in the Rico quadrangle, numerous large bodies of porphyry which have been described belong undoubtedly to the Tertiary period. It is, indeed, possible that these are some of the rocks of the Eocene and the Miocene ages. But no evidence has been found to indicate the particular epoch of this period in which these rocks were formed.

**Erosion and faulting.**—In considering the Rico region bearing on this question is limited to the volcanic rocks. The Rico mountains are very similar to rocks of the Rico region and some of these are intruded into volcanic rocks of the Eocene and Miocene ages. But no evidence has been found to indicate the particular epoch of this period in which these rocks were formed.
the nature of the forces which have produced the Rio uplift, it is apparent that there is a close analogy between the two phases of intrusive action and the two phases of structural uplift. The present body of opinion is not opposed to the theory that the Rio has given heated solutions the necessary access to the limestones at the present time. So far as this is generally assumed, it is difficult to understand how the two phases of structural uplift are to be distinguished. In any case, it is probable that the Rio uplift is an expression of the limestones and species iron occur near a small por-

phyrilie action. —While no evidence can ever be discovered proving that the surface phenomena, some of the processes is the decays of the Rio uplift, more violent those which have absorbed ultramylonite, or by solutions that have absorbed those waters, and the evolution of phyllicite. The phyllicite and hornblende. —If folding and intrusion at the Rio center be referred to the action of the same great force, it is difficult to understand how the limestones and magnesites were not intruded into the strata of the Rio dome, in view of the large porphyry masses of probably contemporaneous origin occurring at hand in comparatively undisturbed beds. The flatfat mass of porphyry, exceeding in bulk all the rocks of the Rio Mountains put together, occurs at the southeastern base of the dome, but similar large bodies occur on the San Miguel River in the Telluride, and on the northwestern base of the Rio uplift. The great thickness of the Rio uplift, which is the result of the combination of the Rio uplift and the north side of the dome structure.

Whether the Dolorosa was flowing in a shallow valley or deep canyon previous to the present dome at Rio can not be surmised, but since the completion of the structure the structure had doubtless cut back through the volcanic rocks which are supposed to have covered the region, and possibly into the Mecocasolid region, it is evident that they are not separated from those of the epoch preceding it. It is the only source of water, so that the Rio uplift had not been removed entirely and that, as in Mount Wilson, to the north, sediments above those now exposed were present, up into the Mesozoic, that is, at the time of uplift.

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 pixmap of the Rio dome.

General statement. —The San Juan and adjacent country appears to have been a continental tract for a time. In the Rio uplift, the Rio dome is clearly of the kind described that it is considered probable that this change is also due to the monoclinal intru-

question. Naturally the work of distinct epochs of Tertiary erosion can not be recognized in the Rio district, and the present discussion is, therefore, limited to the processes of erosion and denudation of the Rio dome. This erosion began with the rise of the dome, at some unknown time in the Tertiary, and continued during the entire Quaternary period, although discussion is here confined to pre- Glacial erosion. The glaciation here referred to is that of the ice sheets and the lobe of the ice sheet which, more or less, is certain to have covered the Rio district, and the discussion is necessarily the earliest of the region, as will be explained in a later paragraph. At the inception of the ice sheet the Rio dome was deeply eroded by the ice and is nearly the same as its present form. When the Rio uplift began to be invaded by ice sheets, many of the formations in the Rio district were too hard to be invaded by ice sheets, but those in the valleys of the Rio district are so hard that the ice sheets invaded them, and the Rio uplift was nearly the same as its present form.
In the valley, the Dolores river has several rapids and small waterfalls, with a current that is fast and clear. The river is bordered by steep cliffs and rocky outcrops. The surrounding landscape is rugged and barren, with occasional patches of grass and small bushes growing in the crevices of the cliffs.

The Dolores river is an important source of water for the local ecosystem, providing habitat for a variety of plants and animals. The river is also a popular destination for recreational activities such as fishing, canoeing, and kayaking.

In summary, the Dolores river is a significant feature of the Colorado Plateau, with a long and varied history. Its unique characteristics and the ecological processes that shape it continue to be studied and explored by scientists and naturalists.

### References

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ECONOMIC GEOLOGY OF THE QUADRANGLE.

By F. L. Hammon.

INTRODUCTION.

The principal ore deposits of the Rice quadrangle are confined to its northeastern corner, and are included within the area of about 95 square miles covered by the Rice special map. The mining district is nearly surrounded on the north by the town of a few hundred inhabitants and the rest of Dolores County, lies nearly in the center of the district, on the Dolores River, which traverses the area from north to south. The Rio Grande Southern Railroad connects the town with the Denver and Rio Grande system at Durango on the south and at Ridgway on the north.

The following general account of the ore deposits is for the most part condensed from a report entitled "The Ore Deposits of the Ríco Mountains, Colorado," published in the Twenty-second Annual Report of this Survey in 1902. To that report the reader is referred for detailed descriptions of individual mines.

HISTORY OF MINING DEVELOPMENT.

Records of the discovery and early development of the Rico ore deposits are fragmentary and often conflicting. The first recorded attempt to prospect the region was in 1863, when Lieutenant Howard and other members of John Bache's expedition into the Sewa and Ram region made their way over the mountains from the east. Eight years later Shaw and his party, in search of Fourkiller, built a cabin on Silver Creek, near its junction with the Dolores River, and located several claims. One of these, the Pioneer, subsequently gave its name to the mining district.

In 1872 E. C. Darling and others erected an adobe furnace and attempted to smelt ore from what are now known as the Atlantic Calamine, Ant, Placer, and Yellow Jacket claims. They were unsuccessful, and it was not until 1877 that active prospecting was resumed in the Pioneer district.

In 1879 rich oxidized silver ore was discovered on Nigger Baby Hill, and the future productivity of Newman Hill was foreshadowed by the shipment to Swam to Swansea of some ore from the Chestnut vein. The town of Rico at once springs into existence.

In October, 1887, the largest and richest of the blacklead deposits on Newman Hill was discovered by David Schickelmann in the Enterprise shaft, at a depth of 262 feet, and shortly after ore was discovered in the Blackhawk, Logan, and Rico-Arpen mines.

The Enterprise mine was sold in 1890 to a Swedish company, and on the advent of the Rio Grande Southern Railway, vigorous exploitation was continued in various parts of the district until 1905, when mining activity showed signs of abatement.

Since 1865 the output of the Pioneer district has decreased. The large bodies of rich "con- tact" ore have been mined out, and many of the veins have been worked down to a depth at which the ore no longer pays for shipment. Mines of ore are often proved to be curiously limited, owing to various conditions that are characteristic of the region and that presently will be described.

The decline in the price of silver had a depressing effect on this or on other districts where this metal forms a large part of the output. But nearly all the important ore bodies formerly exploited were sufficiently rich to be worked to-day had they been mined out. In 1861 the only ore being shipped from the district was an occasional carload taken out by miners working small areas of unexplored ground in the larger mines.

In 1902 practically all the important mines in the district were either out of commission, or the name of the United Rico Mines Company and although no material increase of production has yet resulted, the new company has devoted itself with considerable success to the development of the Atlantic Cable mine and to the experimental treatment of the scheelite ore there found.

PRODUCTION.

The total production of the Pioneer mining district may be only roughly estimated, owing to reports of the Director of the Mint, the output from 1879 to the end of 1905 has been reported as silver and gold and copper. The value of the entire product, including the base metals, probably lies somewhere between $80,000,000 and $100,000,000. By far the greater part of this has been silver. Present developments indicate that the district may soon produce considerable zinc and lead.

PRELIMINARY OUTLINE OF THE ORE DEPOSITS.

The ores of the Rico district show unusual variety in their occurrence, as regards both form and genesis. It is proposed in this report to treat the deposits under four general heads, namely: (1) Lodes, (2) blankets, (3) replacements in limestone, and (4) stocks. This is confessedly and obviously a rough grouping for convenience and clearness of treatment, and is not intended as a scientific classification.

Under the first head will be described simple or complex veins, usually nearly vertical, which when they occur in the sedimentary formations cut across the strata. They are fractures or fissures in the rocks, which have been afterwards filled with ore or valuable vein matter.

Under the second head will be treated various deposits usually more nearly horizontal than vertical, and lying parallel to the planes of bedding or to the surfaces of interstratified sheets of igneous rocks. These are the deposits locally known as "contact." This term, used in a sense that has become common, is not here employed. The meaning, however, has unfortunately found its way into literature and has been so universally adopted by the miners that it is difficult to altogether avoid its use. Wherever employed, however, the word will be placed in quotation marks, indicating its true standing as miners' vernacular.

Under the third head will be considered those deposits, often irregular in form, which have resulted from the metamorphic replacement of limestone by ore.

Lastly, under the fourth head, will be noticed the small ore bodies, their disposition and "relations," of which the Johnson Bull is the principal example in this region.

The most complete list of the various deposits includes those between these various deposits. Lodes of flat dip may pass into bedding faults along weak strata, producing breccias which, in some cases, form the bulk of the deposit. The mineralization of such a breccia, particularly if the material be calcareous shale, is likely to be largely by metamorphic replacement, producing a deposit closely akin to those resulting from the simple replacement of limestone. Moreover, the ore bodies so generated between the second and third heads are always intimately connected with lodes or lenses which may or may not be themselves PRODUCTS.

The greatest part of the product of the district has come from the blankets. Some of the lodes have been proved rich, but their average production has fallen below the limit of profitable working at a remarkably shallow depth, which generally bears a constant relation to some overlying blanket with which the lode or lenses connect. Some important bodies of ore have also been formed by direct replacement of limestone.

The bulk of the ore has been found in the Carboniferous sedimentary series, particularly that portion of it known as the Hermosa formation. This is nearly equivalent to anything that most of the ore has come from the central portion of the district, in the heart of the dome-like uplift of the Rico region.

The ores consist primarily of galena—often highly argentiferous and associated with rich silver-bearing minerals—scheelite, and pyrite, with various gangue minerals. In many deposits more or less complete oxidation of the primary ores takes place, resulting in pulverulent earthy ores, often very rich in silver.

DEPOSITION OF THE ORES.

In all probability more than half of the ore produced in the Rico district has come from Newman Hill, the remainder occurring in a definite area south and east of Rico, constituting the western flank of Dolores Mountain. Newman Hill may be considered as bounded on the north by Silver Creek, on the west by the Dolores River, on the south by Deadwood Gulch, and on the east by the cliffs formed by the massive bed of lime stone characteristic of the medial division of the Hermosa. On this slope, which is deeply covered with surface wash, are the Enterprise, Rico-Arpen, Newman, Union-Carbonate, and other mines, in which the ore occurred partly in lodes and partly in blankets. Of the latter the principal one is locally known as the Newman Hill or Enterprise "contact." Also on the east side of the Dolores River, but north of Silver Creek, is Nigger Baby Hill, a spur of Telescope Mountain. This hill has produced ore since 1789. The ore occurs in oxidized form in lodes, which in their upper portions possess so flat a dip as to constitute essentially blanket deposits.

C. H. C. Hill lies immediately north of Silver Creek. It is a lenticular area, honeycombed with workings from which much ore has been taken. The ore, largely oxidized, occurs in blankets, the continuity of which has been greatly broken by the surface wash. Of the other hill, it may be said that it nowhere occurs in sufficiently large masses, unless possibly in the Atlantic Cable mine, to be worked for its ore alone. It presents no unusual peculiarities in this region and is, as elsewhere, nearly always accompanied by scheelite.

Scheelite.—Zinc blende is an abundant constituent of the rich ores of Newman Hill, which sometimes contain over 15 per cent of zinc. Its common association in these ores is galena, sphalerite, rhodochrosite, and quartz, and it occurs both in the northwestern lodes and in the blankets. It is also found in massive granite form, associated with a little chalcopyrite, galena, and fluorite, in the Blackhawk mine, where it makes up a considerable part of the ore. In the Sanme mine it occurs as galenas, sphalerites, and other minerals occur as replacements of the Devonian limestone. By reference to the geological map we see the predominance of the important ores occurring in the Hermosa, particularly in the lower and middle divisions, will be evident. Near the periphery of the dome, where the Permian, Triassic, and Jurassic sediments now constitute the surface, no large ore bodies have been found. The Johnson Bull, it is true, occurs in Dolores rocks, but the ore body, although at one time giving rise to much mining activity, proved to be little more than a pocket.

MINERALOGY OF THE ORES.

The ores of the Rico district present few noteworthy or peculiar mineralogical features, and are in general similar to those of any other district under consideration. They may be roughly divided into (1) pyrite ores, usually of very low grade, and (2) argentiferous galenas, sometimes with rich silver content and often containing much sphalerite. The pyritic ores constitute the characteristic vein filling of the blankets and lodes and occur in the blankets and other deposits. The galena forms the workable ore bodies, deposited under various favorable circumstances of concentration. The two kinds of ore are not capable of simple minerological or commercial distinction, and are not necessarily of different age. The principal minerals occurring as a direct result of the general processes of mineralization are as follows:

Galena.—This is by far the most abundant sulfide in the district. Associated with quartz and small amounts of chalcopyrite, sphalerite, and pyrite, it constitutes the practically worthless filling of most of the lodes. It is found in large blanket-like masses, free from gangue, in C. H. C. Hill. In similar masses, but in more solid condition, it is found as a replacement of limestone. This is the mode of its occurrence in the Blackhawk mine, where it is frequently associated with fluorite and grades by increase of chalcopyrite and galena into workable ore. Although commonly containing small quantities of silver and gold, the pyrite has bitherto proved too low in grade for successful treatment. Eckard records that the pyrite from the northwestern lodes in the Enterprise mine usually averaged from one to 4 to 8 ounces of silver and traces of gold. In the Fish Anchor prospect in Bull Basin a large body of pyrite was found which is said to have indented, in small masses, as much as 90 ounces of gold per ton, but which as a whole did not pay the cost of extraction.

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Talnacherite.—Gray copper ore occurs in the
rich blankers ore of the Enterprise and Risco-Apis ore
mineral in some of the northwesterly lodes. It is also
a valiant competitor for the use of its esteemed, tiferous
character. It is here associated with sphale-
nite, polybasite, galena, rhodochrosite, and quartz.
It occurs in the rimes and blanket that has replaced
gypsum, the gyspum being melted out of its.

A more transparent crystalline form of gypsum, known as
sohnite, is associated with rhodochrosite and polybasite,
as a replacement of sandstone in the Gold Anchor
prospect in Bull Run. It is partly present also in
the Axte lode, with chlorite epige, and may have
formed part of the Axte blankers ore. A small
piece of tetsabrice was extracted from the Iron
boul, but the mineral apparently does not occur in
this great replacement deposit of this mine. A little
rhodochrosite occurs, with quartz, in the Eureka, a
prospect near the head of Iron Drain. It is now scarce
and absent, and its presence is generally indicative
of high-grade ore, although not necessarily in large
amounts.

Epiclina.—This mineral, a sulphamate of copper, occurs
at the head of Horse Creek in the Johnny Blankers.

Sparsoids.—The crystalline variety of hematite occurs
abundantly in several mines and prospects in the
metamorphosed Devonian beds near Rico. It seems
to name the Iron Bulls, Eighty-Eight, Atlantic Cave, Shumaker,
and Snaggle. It is closely associated with chlorite,
ehellite, ore, garnet, and perhaps quartz. Its
appearance, pale, yellowish-vousmanite as well
as with galena, sphalerite, and chlorite, and its formation was evidently
connected with the alteration of the
Devonian limestones. It is of no value as an ore
in this region, but has been sometimes mistaken for
some other mineral.

Magnetite.—This mineral has been mined in
small amounts for mixing purposes from the
Magnet prospect on the north side of Darling Ridge
and from the Eagle prospect near the head of
Sulphur Creek. It occurs massive, with a little chlorite
epige, replacing the black blankers ore. It may contain
an ounce of silver and 82 in gold per ton.

Argyrol and silver-bearing minerals.— Argyrol, pyrargyrite, and perhaps
stephanite are the rich blanket and lode
ores of Newman Hill. They were evidently
among the last ores to form, and to
them are mainly due the richness of these deposits.
They are almost invariably found in
veins in the more solid ore, and when present in these veins occur along the central plane of the
vein in the spaces left by the comb structure of the quartz and other minerals. Argyrol is found in small masses of
rounded masses, suggestive of particles of shovemaker"s waste which have softened and fallen
off the walls of the veins and are occasionally found in the country rock.
Polybasite and arsenopyrite also occur in veins, but in
implanted crystals of the forms characterizing these minerals, and in the
rimes and blankers ore of the
silver deposits. This mineral is occasionally found in small masses of
visit, but its occurrence has been reported by Fairlie, who also mentions pyrargyrite. These
minerals are typically found in the
country rock, where in the district 1900; but argyrol is said to have occurred in the
Puzzle mine, in a quartz vein, replacing limonite.

Silver.—Native silver is reported from the
Enterprise and Puzzle mines, but none was seen in 1900.
It was probably a product of oxidation.

Gold.—Free gold is rarely detected in the Rico ore deposits. Some is said to have been found associated with sphalerite and chlorite in the
Enterprise mine, and some embedded in rhodo-
chrosite in the Eureka vein of the
district. A little free gold has been found in the
Carlow Park, but none was seen in place. The
ore of the Johnny Blankers mine contained con-
siderable gold, with tellurium and trace of thallium,
but it is not known whether any of the gold
curred native. Gold, associated with a little molbendite, occurs in the
Rico Blankers mine, as small crystals in the country rock.

Quartz.—This is by far the most abundant
blankers ore mineral in the region. It is usually present
in the workable ore, it is there associated with
other gangue minerals. The lode quartz shows no
special features peculiar to this region, and requires
no special description. The quartz in the
Enterprise and Blankers ore is a cryptocrystalline aggregate commonly associated with replacement deposits) quartz occurs in the
black Blankers ore. In the Axte Blankers ore, and in the Blankers mine, quartz is found in connection with the C. H. C. Blankers blanket.
In the former mines, also, ore found spongy
masses of rusty quartz, apparently due
to the removal of limonite, which forms a network of quartz stringers. Quartz is abundant in some of the blanket breccias as a replacement of the brecciated material. In the case of the nearly
black quartz blankers ore, it is still
recognizable as dark patches in the white quartz, although the microscope shows that they are not of any family.

Among the gangue minerals, the main blanket of the Union-Carbonate mine fragments of moneous-porphyry have been more or less completely transformed into very spongy masses of white quartz, sometimes
containing pyrite. A somewhat similar sifification
of porphyry has taken place along the lode
features of the Malowick and Markeg Stakes prospects
in Horse Gulch. In these cases, however, the resulting siliceous skeleton still preserves, in a measure, the original porphyritic appearance of the rock.

Rhodochrosite.—The carbonate of manganese is present in the rich upper portions of the northeasterly lodes of Newman Hill and in the Enterprise blanket, and it is a valuable mineral. It is
compatible and recognizable, and it is important in these mines as a rough indication of good ore. It occurs massive, often as a thin film, covering the quartz veins and ore of the lodes. It does not, as far as
known, occur in this region in the large, well
formed crystals which characterize this mineral in some other localities. A little residu-
ual rhodochrosite was noted in the oxidized Little Blankers ore; but it is not generally abundant outside of Newman Hill. Some
of the "spur" veins in other portions of the region appear to be a development of this variety; and it is
run in part to black oxide of manganese, showing either that some of this mineral is present or that the rhodochrosite is secondary.

Calcite.—This mineral, the common "spur" of the
miners, is abundant only in the veins of Nigger Baby Hill, where it takes the usual place of quartz as the principal gangue mineral. It is generally
finely crystalline, more or less impure, and often resembles ordinary limonite. It is always
manganiferous, and readily decomposes under conditions, whereby the calcite carbonate is largely removed and a soft black mass of oxidized magnonferous ore left behind. Calcite is naturally often present as gangue in the replacements of limonite by ore. The appearance of the
Blackhawk mine was not identified at the time of visit, but its occurrence has been reported by Fairlie, who also mentions pyrargyrite. These
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but they contain no ore, and can not be individually correlated with those below it.

The conditions which limit the northwesterly fissures in length are not well known, as apparently none of them have been worked to the point of disappearance. Toward the southwest some of the more northerly extend for a great distance and cut off by the Deadwood fault. Toward the northeast it is probable that the prominent northwesterly fissures known in the Espey, C. H. C., and C. Hill and probably corresponds to the Pigeon lode, or so-called “big fissure” of that hill, and contains a quartz-calcite fill. The last-mentioned lode and all the others are continuous, also, that the A. R. G. lodes, on the west side of the river, is on a bench of the same fault, and that the mineralization in the level of the fissure. Details of the Blackhawk fissure are difficult to obtain. It is the largest and most prominent of the northwesterly fissures, being about 40 feet in width. It is not likely, however, that an opening of this space existed at any one time. At least one of the fissures indicated by the surface of the fissure, and are located on the same bench.

Intimately connected with the Blackhawk fissure are several fissure workings along about 700 feet, and then it is probable that the fissure was opened by normal faulting, and in some cases are reported to have failed the overlying blanket in the east part of the fissure. Vertical displacement to this amount is, however, rather exceptional. Moreover, as will be seen later, the structural relations of the northwesterly fissures shows that a considerable part of the observed faulting may have taken place since the fissures were first formed.

In the Union-Carbonate mine, on the northern slope of Dolores Mountain, the fissures show less resemblance to those of the eastern portion of Newman Hill. The productive northwesterly fissures are not developed. Numerous other fissures are found striking from N. 60° E. to N. 75° W.—that is, more westerly than the northwesterly veins of the Enterprise mine. Fissures of this general trend are dominant on the northern slope of Dolores Mountain, as shown in the Union-Carbonate and Forest-Payroll workings.

Outside of Newman Hill, northwesterly fissures are of small importance. Several have been worked at the eastern base of Exposition Mountain, between Sulphur Creek and Iron Dray, in the N. 4. Cow-drey, Tomule, Argonaut, and Banero mines. The strikes of these fissures range from N. 40° E. to N. 60° W., and the average dip northeasterly at about 25°, although the Coblerd vein is steeper. As these fissures are followed downward, their dips are found to increase. The Phoenix vein, with dips sometimes as low as 15° in the upper workings, steepens to 45° in the lower workings, on the southern slope of the hill. The strike of the fissures is found to be more westerly as they are followed northwestward, toward Silver Creek.

The Iron lode, on the southeastern slope of Nigger Baby Hill, strikes N. 10° W., and dips northwestward, in a direction not more northerly than the majority of the lode fissures on the hill.

The Hope, or Grand View, Cross, Phoenix, and Nellie Bly fissures are notable from the fact that their strikes are very nearly parallel to those of the lode fissures on the hill, and to this extent are generally slightly steeper in angle, correspond in direction to those of the strata. Consequently these fissures cross the benches of the lode fissures at right angles, having an acute angle, causing the lodes, particularly in direction to those of the strata. Consequently these fissures cross the benches of the lode fissures at right angles, having an acute angle, causing the lodes, particularly in detail of the hill, to a great extent in the form of an irregularly-shaped block of rock.

The main fissure, on which are located the Blackhawk, Argonaut, and Uncle Ned mines, has a general northerly trend, but changes from N. 10° W. at angles varying from 50° to 80°. The geological work of Cross and Spencer has shown that this fissure is part of a pronounced zone of faulting which they have called the Blackhawk fault. The fissure is well known, as apparently none of them have been worked to the point of disappearance. Toward the southwest some of the more northerly extend for a great distance and cut off by the Deadwood fault. Toward the northeast it is probable that the prominent northwesterly fissures known in the Enterprise, Newman, and Ries-Apennine mines do not persist across the thick intrusive sheet of monzonite-porphyry which rises up over the northern slope of Newman Hill. They may either die out before reaching it or be deflected into other courses.

None of the northwesterly fissures have been exposed to great depth, but the section afforded by the Lexington tunnel, about 400 feet below the Newman Hill blanket, shows that they are shallower at this depth than in the workings above.

The northwesterly fissures of Newman Hill are more abundant than the northeasterly, but as they contain no workable ore, they are seldom drifted on and are consequently not so well exposed as the latter. Their dips range from vertical to about 45°, and may be northeast or south, the former being more common. The average dip is lower than that on Nigger Baby Hill. They vary greatly in width, from a mere crevice up to 3 or 4 feet. Although often simple fractures, they are frequently slight blue micaconch ornaments. The fissures appear to have been opened by normal faulting, and in some cases are reported to have failed the overlying blanket in the east part of the fissure. Vertical displacement to this amount is, however, rather exceptional. Moreover, as will be seen later, the structural relations of the northwesterly fissures shows that a considerable part of the observed faulting may have taken place since the fissures were first formed.

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It appears from the foregoing that the northwesterly fissures which have proved so productive in Newman Hill are characteristic of but a small part of the district, comprising roughly the southern half of Newman Hill and that part of the base of Exposition Mountain lying between Sulphur Creek and Iron Dray, in the Coblerd, and Argonaut mine, north of Piedmont; in the Antic vein, in Antic vein; in the California and Zulu Chief mines, near the head of Iron Dray; and apparently also in the Eighty-Eightve-Eight, on Silver Creek.

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the depth the valuable silver minerals disappear gradually near the bottom of the veins, which above produced ore containing many hundreds of ounces of silver per ton, becomes progressively less concentrated, and it is evident that the contact between the Newman Hill veins at depths varying from 350 to 500 feet below the blanket, they are small and generally barren, consisting of quartz and some little pyrite.

Oxidation of the loess.—In the southern part of Newman Hill, the loess overlying the Newman Hill blanket and as the latter is protected from the free access of surface waters by an impermeable layer of "clay" or "humus," oxidation has played but a minor part in the development of the ore bodies. Is the Union-Carbondale mine some oxidized ore was seen which is not from a northerly vein.

The depth to which oxidation has penetrated in Nigger Baby Hill is apparently variable. Owing to the steep sides and the natural depression of the hill, the permanent ground-water surface is low, and oxidation has probably nowhere extended down to it. The process has been retarded by a nearly impermeable layer of very local physical and chemical factors and by time. From the extent of the old stops it appears probable that complete oxidation extends for about 200 feet from the present surface of the hill near its summit, growing less as the depth increases.

Production was undoubtedly greatly facilitated by the fact that the veins contain a calcite and not a quartzose gneiss. The impure calcite is dissolved away, leaving behind a residuary, a soft residue, consisting chiefly of hydrous oxides of manganese and iron, with some siliceous and aluminous matter. This soft black or brown material is sometimes rich in silver.

The alteration of the upper portions of the Little Maggie and Allegheny veins is somewhat similar to that described. The Little Maggie vein, however, seems to have contained more copper than is present in the Nigger Baby Hill veins, and some residual kernels of pink rhodochrosite were noted.

Relation of the loess to faults.—The relation of the loess to the important structural features established by the geologic mapping is neither close enough nor obvious to a person geologic student might be expected.

Productive loess does not occur in the fissures of contact between the Blanket and Loess, nor in the fissures drawn on the geologic map, not one has been shown to contain any large bodies of ore. The Blanket loess, which does not itself contain workable ore, is also a large fault, but it is by no means certain that it fills the actual fault fissures. However, that some may be present in the Sharkov fault, in C. H. C. Hill. The A. B. G. lode, at Burna, is possibly on a branch of the Sharkov fault. It contains some low-grade ore, which, however, never been worked on a commercial scale. The Nellie Bly fault certainly does not coincide with the Nellie Bly vein, but appears as a close, inconspicuous fissure a few feet south of the vein. It is possible that the western extension of this fault passes through the Axob and Zulei Chief lodes, but these properties can scarcely be classed as productive. The Last Chance fault, although its designation from structural points seems to be certainly not identical with the Last Chance loess fissure, it is shown on the map as passing through the workings of the Gartner, an unproductive prospect on the west side of the river. None of the old fissures of faults and fissures may be justly summed up in the statement that the most productive loess fissures of the district show little faulting along the strike; that the fault fissures of sufficient extent to be structurally important contain little or no ore. It is but fair to remark, however, that the fault fissures have been unusually prospected.

Considerable structural faults may also be important in displacing loess which they cross.

It is highly probable that the Deadwood fault, at the junction of the New River reef, will place the hanging blanket and ore, throwing their southern continuation downward and westward. A zone of faults which extends down to the broken surface past the Lauf shaft, has probably offset the lodes on the north. Neither of these points, however, can be determined underground at the time of this visit.

The Nellie Bly fault, which passes over the end of Nigger Baby Hill is a northerly fissure and has been offset by the Lauf shaft, but does not appear to have caused much dislocation of the vein material. It seems necessary to conclude that these veins are of later origin than the fault.

Relative ages of the loess.—The question of the relative ages of the northerly and northerly veins of Newman Hill is of theoretical and practical importance. The observed phenomena that bear on the question may be briefly summarized as follows:

(1) The lodes of the two systems are distinctly different in trend.

(2) The northerly lodes are practically parallel with the Trend of the beds. The northerly lode of Newman Hill contain rich ore to a depth of about 150 feet below the Newman Hill blanket.

(3) The northerly vein was present about two or three generations of quartz and pyrite.

(4) The northerly veins, when not too much altered, are better developed and easier to follow due to repeated openings and fillings.

(5) The northerly veins are solid and often contain large quartz veins; the northerly lodes are almost invariably cracked and accompanied by gangue.

(6) The northerly fissures generally cross the others without being themselves deflected.

(7) In some cases the northerly fissures are separated from the others by a fault, and in such cases the northerly vein is cut by a northerly fissure not always comparable in amount with the offset of neighboring veins cut by the same fissure.

(8) Northerly veins are sometimes lost at the crossing of a northerly vein, as was the case with the Hinrich at the 100-foot level of the Enterprise mine and the Chestnut and Newman veins in the Newman mine. It has been assumed in such cases that the northerly vein was faulted and offset for distances up to 175 feet. It is to be noted that the northerly veins were northerly lodes, but small stringers are sometimes present, continuing beyond the latter. In favorable cases, such veins from the northerly veins cut by a northerly fissure are not always comparable in amount with the offset of neighboring veins cut by the same fissure.

(9) Northerly veins sometimes connect or divide small stringers on approaching a northerly lode.

(10) None of the loess fissures displace the overlying blanket more than 25 feet, most of them much less than this.

In one case (that of the Jumbo No. 3 vein, Enterprise mine) a northerly vein is known to turn into a northerly fissure for a short distance and then resume nearly its normal course. The deflected portion of the vein has been brecciated, and successively heated by white quartz, which was later shattered in its turn. In a few rare instances small northern lodes have been observed containing the same ore, suggesting that some of the northerly lodes may be earlier and some later than the northerly lodes, or that they are close enough to disprove this latter view, it is not considered probable.

Beyond the bounds of Newman Hill, it is found that the relative age relationship exists between the northerly and northerly lodes on the west side of the Dolores River, between Sulphur and Iron creeks. In other portions of the district, however, there is some tendency for determining the sequence of lode fissures different trend. As already noted, the northerly lodes are absent or insignificant.

Blanks.—Of the various blanks occurring in the Rito district, the so-called Newman Hill or Enterprise "contact" is most important. This is, for the most part, an unmetamorphosed zone occurring between the top and bottom of the series of sandstones, shales, and limestones which make up the lower division of the Hermit Formation in the southern half of Newman Hill, but its extent is only approximately known. On the west it should continue along the bluff south of the Lauf shaft. On the east, the Rito-Asheville and Enterprise mines, were not for the thick crack of wash which conceals the rock in place. The normal structure of the general series is either dip of the beds (about 15°) and passes under Dolores Mountain. On the north it has not been definitely determined. The Lauf shaft is.

Blanks occur to the north in the Union-Carbondale mine, but none of them has been identified as the "Enterprise contact." On the south the blanket is cut off by the Deadwood fault. As the lode turns south, it passes through a rapidly increasing southerly dip and passes out of reach of the present workings.
The blanket as thus far described, consisting of shale breccia and gray shales of a peneplutonic type, has been locally modified through processes connected with ore deposition. The results of these processes are (1) post-mineral veining, (2) post-lithification processes, and (2) deposition of ore. Both of these modifications are directly connected with the lode fissure itself. But the blanket is not the blanket rock, but it sometimes extends up into the breccia, where it may, perhaps, have formed part of the filling of the fissure, or even as a replacement. It often partially replaces the breccia limestones, particularly where the latter is breciated.

In the vicinity of the Vestal shaft and in portions of the Enterprise mines ore occurred in the gypsum itself. It was found as irregular lenses in the lower part of the bed, having metasomatically replaced the gypsum. Such ore has a gangue of quartz, rhyolite, and copper.

The usual blanket ore of the Enterprise and Rio-Arpa mines is similar to that of the northwestern lodes, but presents variations which are always sufficient to identify it. It is usually less solid and shows less regular bedding or none at all. It consists of gneiss, epidote, and one or more mineral-bearing minerals in a quartz and chlorite-calcite gneiss which is often subordinate in amount. The iron pyrites are usually abundant as in the lodes. With the foregoing minerals are often associated small amounts of chalcopyrite and sometimes argentiferous tetra- hedrite. Common pyrite is apparently very subordinate in the rich blanket ore. The rich silver-bearing minerals in the district are sphalerite, galena, and some lead-silver sulfides, including galena, pyrite, and chalcopyrite. The latter is very abundant in the ore bodies. The black streak is usually described as black with a green tinge. The black streak is usually described as black with a green tinge.

In addition to the main blanket of C. H. C. Hill, several blanket-like masses of pyrite occur at other horizons in the stratigraphic series. These bodies are not distinguished from the main blanket by the absence of quartz and pyrite containing bodies of low-grade ore.

The blanket just described occurs several smaller and less important ones of different character. These are found in bed of dark shale, pro- truding in the gypsum as well as lying within the uptake, and involving replacement. The change in this case involves the removal of some of the quartz, with the accumulation of much siderite and small quantities of limonite, arsenite, and some more hydromagnesium minerals.

In addition to the main blanket of C. H. C. Hill, several blanket-like masses of pyrite occur at other horizons in the stratigraphic series. These bodies have been described as being composed of a mixture of pyritic sulfides and metals, forming the schistose lode. The lower blanket is extensively attacked and removed by chemical processes, with the formation of a thin layer of tufa, halite, and other carbonates, forming a halo around the lode. The blanket-like masses are often associated with the development of a thin layer of tufa around the lode. The blanket-like masses are often associated with the development of a thin layer of tufa around the lode. The blanket-like masses are often associated with the development of a thin layer of tufa around the lode. The blanket-like masses are often associated with the development of a thin layer of tufa around the lode. The blanket-like masses are often associated with the development of a thin layer of tufa around the lode. The blanket-like masses are often associated with the development of a thin layer of tufa around the lode.
The vertical extent of the original Rico uplift is as yet uncertain. A portion of this, however, is essentially due to the occurrence of the Union-Cambrian system, which seems to owe its existence chiefly to bedding faults. This is so far well authenticated as to the correctness of the blanket named are actually pure fault breccias. It is quite possible that some of them may have been affected by the solution of the same rocks as in the New-hammer and the traces of such genese have been obliterated by subsequent movement.

The stratigraphic conditions of some of the strata of the Rico district, only a relatively small number of the bodies have been themselves productive, and those to a considerable extent. In the Rico district, the rocks under gravity are underlain by an episode of vigorous faulting and uplifting. Pay shoots.—The superficial character thus far outlined is one of the most interesting phenomena of the Rico district and vitally concerns the operation of its mining industry. As outlined in the preceding sections, only a relatively small number of the bodies have been themselves productive, and those to a considerable extent. In the Rico district, the rocks under gravity are underlain by an episode of vigorous faulting and uplifting. Pay shoots.—The superficial character thus far outlined is one of the most interesting phenomena of the Rico district and vitally concerns the operation of its mining industry. As outlined in the preceding sections, only a relatively small number of the bodies have been themselves productive, and those to a considerable extent. In the Rico district, the rocks under gravity are underlain by an episode of vigorous faulting and uplifting.
as a second hypothesis, that the blanket ore may have been formed, before the local changes of the Sonoita Shoot, by the full opening of the northwestly fractures, and that the nonoccurrence of ore in the northwestly part of the deposit may have been caused by the erosion of the ore body. The ore appears to be well-limbed and to border the main ore body. The ore is rich in iron and contains a large amount of pyritic matter in the form of pyrrhotite and stibnite. The ore is usually hard and dense, and the amount of pyrite ranges from 20 to 40 per cent. The ore is probably of hydrothermal origin and is associated with the volcanic rocks of the region. The ore is highly valuable and contains a large amount of iron and other valuable minerals.

Sources of the ore.-The area of the Rio district was highly mineralized, and the ore bodies were well developed. The ore bodies are usually well-limbed and contain a large amount of pyritic matter in the form of pyrrhotite and stibnite. The ore is usually hard and dense, and the amount of pyrite ranges from 20 to 40 per cent. The ore is probably of hydrothermal origin and is associated with the volcanic rocks of the region. The ore is highly valuable and contains a large amount of iron and other valuable minerals.

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<table>
<thead>
<tr>
<th>Formation Name</th>
<th>Juncal Beds</th>
<th>Thickness of Beds</th>
<th>Character of Formations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maroon Shale</td>
<td>8 m</td>
<td>180-1</td>
<td>Soft, dark gray, or almost black, unstratified claystone containing thin layers or lenses of various structures. Embedded in the Colorado group and a part of the Pene division of the Morrison. Fossils occur more or less abundantly at several horizons.</td>
</tr>
<tr>
<td>Dakota Sandstone</td>
<td>15-20 cm</td>
<td>140-240</td>
<td>Gray or gray-brown, pisolitic or nodular sandstone. Small-scale pisolites are round. Carboniferous sandstones occur at several horizons and are of good quality. Individual sandstone beds are thinly interbedded.</td>
</tr>
<tr>
<td>Molino Formation</td>
<td>15-20 cm</td>
<td>40-100</td>
<td>A complex of alternating feldspar, fine-grained, pisolitic or nodular sandstones and shales. The sandstones are seldom more than 5 feet thick. They often include slates of grayish or clay-colored color. The shales are purplish to blue, but may be pink, gray, red, or chocolate brown. Some shale layers are sandy and others highly argillaceous. No fossils have been found in the Molino area.</td>
</tr>
<tr>
<td>La Plata Sandstone</td>
<td>15-20 cm</td>
<td>25-100</td>
<td>Consists principally of two massive, friable, white sandstones, each with a narrow band of dark sandstone or calcareous shale between. The sandstones are quartzites of various grades, the coarsest being the streaky, grayish-white sandstone of lower thickness. The dark layers are locally interbedded or reconstituted. No determinable fossils have been found.</td>
</tr>
<tr>
<td>Jurassic-Subjacent Unconformity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juncal Beds</td>
<td>15-20 cm</td>
<td>80</td>
<td>Sandy, red, fine-grained sandstone and shale of bright red color with fine lamination suggesting a water level. The shale layers are more numerous, with a very gneissoid structure similar to gneiss, indicating the Triassic age of the formation.</td>
</tr>
<tr>
<td>Oways Limestone</td>
<td>15-20 cm</td>
<td>180-200</td>
<td>A complex of bright red sandstones and lighter red or pinkish grits and conglomerates alternating with sandy shales and marly or muddy layers of varying shades of red.</td>
</tr>
<tr>
<td>Peso Quarzite</td>
<td>15-20 cm</td>
<td>180</td>
<td>Dark reddish-brown sandstone and pink grit, with interstitial greenish or reddish shale and sandy, fossiliferous limestone.</td>
</tr>
<tr>
<td>Hermes Formation</td>
<td></td>
<td>180-200</td>
<td>A series of grits, sandstones, shales, and limestones of varying distribution and development. Dark and shales are massive except for a few parallel and of a more massive character. The lower portion consisting of thinner bedded sandstones, shales, and limestone layers. Numerous interbedded shales occur in shale and limestone.</td>
</tr>
<tr>
<td>Oways Limestone</td>
<td>15-20 cm</td>
<td>180-200</td>
<td>Dark red, brown, and greenish sandstones and shales, with intercalated greenish or reddish shale and sandy, fossiliferous limestone.</td>
</tr>
<tr>
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<td>15-20 cm</td>
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</tbody>
</table>

*WITHAM CROSS*

*ARTHUR C. SPENCER*

*Geologist*
Fig. 1—The Southeastern Peaks of the Rico Mountains, from the West Side of the Dolores River.

In the centre is the upper face of the northern face of Shishke Peak, behind which is Rockpress Peak. To the left is the north shoulder of Blackburn Peak, with its snow-capped summit. On the right is the north face of Sheep Mountain, with its precipitous cliffs, and in front is the domed summit of Salsbury Peak. Across the face of Dolores Mountain may be noted the serrated ridges in the middle of the Mesozoic formation.

Fig. 2—Sandstone Mountain, Looking Across the Dolores from the Foot of C. H. C. Hill.

The view illustrates the manner of the origin of the towers formed by the crumbling of the fragments, and the erosion of the Mesozoic formation and the same zone of the lower portion of the Dolores red beds in the south to the right. The alpine crossing of the summit of Sandstone Mountain made the tree of airmed fells.

Fig. 3—Darling Ridge and Horse Gulch, from Sandstone Mountain.

At the head of Horse Gulch, on the right, is Celilo Peak, and on the left is the Alp Missoula. The snow-capped slope of Darling Ridge on the left, from the creek to the treeless crest, is wholly occupied by landside debris. The Puzzo creek is situated at the foot of the scree slope in a saddle between.

Fig. 4—Torrential Fan at the Mouth of Atepe Gulch, from East Side of the Dolores River.

Shows the characteristic form and grade of a torrential fan. The face at the bottom of the main fan is an erosion scarp cut by the river. A secondary fan is now being formed in front of that scarp.

Fig. 5—Telescope Mountain and the Upper Part of C. H. C. Hill, from Sandstone Mountain.

The highest point is the summit of Telescope Mountain. On the left is a stand of Mesozoic and Mesozoic rocks. On the right is the ridge leading down to Negro Billy Hill. The foreground and central part of the view shows the eroded formation of C. H. C. Hill. The Puzzo creek, or 'Big creek,' runs beneath the stream through the wash. The Puzzo creek belongs to the Menard.

Fig. 6—Details of Landslide Topography in the Area on the North Side of Horse Gulch.

The view shows characteristic landside trenches, ridges, and mounds, where disintegration has proceeded so far that secondary forms of side slopes. In the foreground are strongly contrasting ledge outcrops.
As sedimentary deposits or strata accumulate the youngest rest on those of older ones, and the relative ages of the deposits may be determined by observing their positions. This relationship holds even in regions of intense erosion, like a canyon, or in such regions sometimes the beds have been deformed, and it is often difficult to determine their relative ages from their positions; then fossils, or the remnants and imprints of plants and animals, indicate which of two or more formations is the oldest.

Sedimentary rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land and buried in silicious deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex forms developed, and as the simpler forms lived in more modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types of fossils are found on period after period, and thus the link of life from the oldest fossiliferous rocks to the present. When two sedimentary formations are found in the same area, and neither one is older and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which is the older of the two. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for establishing local histories into a general earth history.

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

Symbols and colors assigned to the rock systems:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Gray</td>
<td>Normal rocks</td>
</tr>
<tr>
<td>C</td>
<td>Blue</td>
<td>Carboniferous and sandstone</td>
</tr>
<tr>
<td>D</td>
<td>Yellow</td>
<td>Devonian</td>
</tr>
<tr>
<td>R</td>
<td>Red</td>
<td>Red beds</td>
</tr>
<tr>
<td>G</td>
<td>Green</td>
<td>Gneiss</td>
</tr>
<tr>
<td>S</td>
<td>Black</td>
<td>Schists</td>
</tr>
<tr>
<td>H</td>
<td>White</td>
<td>Hornblende</td>
</tr>
</tbody>
</table>

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and volcanic deposits. Patterns of triangles and rhomboids are used for igneous formations. Metamorphic rocks of unknown origin are represented by a black symbol printed at each outcrop; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure.

The various geologic sheets:

Areal geology map.—This map shows the area occupied by the various formations. The mountain is a symbol, which is the key to the map. To ascertain the meaning of any colored pattern its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation its name should be sought in the legend and its color and pattern noted, when the area on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

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

The plan of the section in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and slates, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to the right of the outcrops of a bed of sandstone. The upturned edges of this bed form a ridge and the interior valleys follow the outcrops of limestone and chert.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by museums of igneous rock. The schists are much contorted and their arrangement underground cannot be inferred. Hence that portion of the section delimits what is probably true but is not known by observation or inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The apparent depth of the sea at the left of the section, is set of sandstones and slates, which lies in a horizontal position. These strata are not high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called conformable.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by denudation. The beds, like those of the first set, are conformable. The horizontal strata of the plateau rest upon the eroded, arched edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks rest upon an eroded surface of older rocks the relation between the two is described as unconformable and one, and their surface of contact is called an unconformity.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were subjected to pressure and traverred by currents of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of erosive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

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

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

The rocks are briefly described, and their characteristics are indicated in the columnar diagram. The thicknesses of formations are given in figures which show the greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

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

CHARLES D. WALKOTT,
Director.

Revised January, 1904.
<table>
<thead>
<tr>
<th>No.*</th>
<th>Name of folio</th>
<th>State.</th>
<th>Price.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Livingston</td>
<td>Montana</td>
<td>$5.00</td>
</tr>
<tr>
<td>2</td>
<td>Ringgold</td>
<td>Georgia-Tennessee</td>
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</tr>
<tr>
<td>3</td>
<td>Placerville</td>
<td>California</td>
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</tr>
<tr>
<td>4</td>
<td>Richmond</td>
<td>Kentucky</td>
<td>$5.00</td>
</tr>
<tr>
<td>5</td>
<td>Sacramento</td>
<td>California</td>
<td>$5.00</td>
</tr>
<tr>
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<td>Chalcoaming</td>
<td>Tennessee</td>
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</tr>
<tr>
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<td>Pike's Peak</td>
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</tr>
<tr>
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* Payment must be made by check or postal order.
* These folio are out of stock.

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