DESCRIPTION OF THE OURAY QUADRANGLE.

By Whitman Cross, Ernest Howe, and J. D. Irving.

GEOGRAPHY AND GENERAL GEOLOGY OF THE QUADRANGLE.

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INTRODUCTION.

LOCATION AND AREA OF THE QUADRANGLE.

The Ouray quadrangle is situated in the southwestern part of Colorado and is bounded by parallels 38° and 38° 15′ and meridians 107° 30′ and 107° 45′; its area is 234.87 square miles. Parts of Ouray, Hinsdale, and Gunnison counties are included in the quadrangle. The town of Ouray, a local mining center, is near the southwest corner, at the head of the Uncompahgre Valley; it is connected by a branch line with the Denver and Rio Grande Railroad at Montrose. The relation of the Ouray to other quadrangles of the San Juan region is shown by the index map on the title-page of the folio cover.

OUTLINE OF THE GEOGRAPHY AND GEOLOGY OF THE SAN JUAN PROVINCE.

The term San Juan region, or simply "the San Juan," used with variable meaning by early explorers, and naturally with indefinite limitation during the period of settlement, is now generally applied to a large tract of mountainous country in southwestern Colorado, together with an undefined zone of lower country bordering it on the north, west, and south. The Continental Divide traverses this area in a great bow. The principal part of the district is a deeply scored volcanic plateau, more than 3000 square miles in extent, drained on the north by tributaries of Gunnison River, on the west by tributaries of Dolores and San Miguel rivers, on the south by numerous branches of the San Juan, and on the east by the Rio Grande. All but the Rio Grande drainage finds its way to the Gulf of California through Colorado River.

The San Juan Mountains, as that term is now understood, embrace the area bounded on the north by the generally abrupt descent to the sloping mesas extending for 25 miles to the canyon of the Gunnison, on the west by the great plateau of Colorado and Utah, on the south by the more gradual descent to the rolling plateaus of New Mexico, and on the east by the broad and level San Luis Park. From this main area a broad spur leads off to the southeast, losing its mountainous character near the Colorado-New Mexico line. The San Juan Mountains thus have a length of nearly 80 miles east and west and a width of 25 to 40 miles north and south, and their summits form a great group rather than a range.

In the western part of the San Juan Mountains the topography is very rugged. There are hundreds of summits exceeding 13,000 feet in elevation, and several which reach more than 14,000 feet above sea level. Here, too, the bounding scarps of the group are in many places very precipitous, and some of the valleys in the heart of the mountains have been cut down to 9000 feet or less above the sea. To the east the configuration is less rugged, and high table-lands, of varying extent, represent in a measure old plateau surfaces.

Within the bordering zone of lower country, having a general elevation of 6000 to 9000 feet, are situated several small groups of high peaks bearing special names. The Needle Mountains on the south, the La Plata and Rico groups to the southwest, and the San Miguel Mountains on the west are the most important of these outliers.

The Needle Mountains are almost continuous with the San Juan proper, but the local name is amply justified by the character of the group, which is a result of its geologic structure. The La Plata Mountains form an isolated group, and the Rico Mountains also are not connected with the San Juan in origin. The eastern summits of the San Miguel Range—the Mount Wilson group of the Telluride quadrangle—are geologically a portion of the San Juan, cut off by erosion.

Though the San Juan Mountains are surrounded by an arid plain country the annual snowfall and rainfall upon them is heavy, especially on the western portion. The higher peaks and basins are seldom entirely free from snow. This abundant moisture supports a heavy forest growth in many places on the western and northern sides. Spruce and aspen cover the higher slopes, yielding to white pine, scrub oak, piñon, and cedar on the flanks, as the streams sink into canyons cut in the lower plains of sedimentary rocks. Timber line lies in the zone between 11,500 and 12,000 feet above the sea, and large areas in the interior are thus barren of tree growth and support only a low alpine flora on favored surfaces.

Valuable deposits of the precious metals have been found in many parts of the San Juan region. Coal beds of great extent and fine quality occur along the southern base, and agricultural lands form the valley bottoms and certain of the lower slopes adjacent to the snow-fed streams from the mountains. With the development of these resources several important towns have been established in sheltered valleys on all sides. Railroads encircle the group and penetrate to some of the mining centers of the interior. Creede, Silverton, Telluride, Ouray, and Lake City, all situated in mountain valleys, are thus connected with the main lines of traffic.

The geologic history of the San Juan region is too complex and as yet too imperfectly known to justify even an outline statement of satisfactory accuracy. The pre-Tertiary surface of the entire region was completely buried by the volcanic formations which now cover the main area, and, while erosion has again exposed some of the older rocks on all sides of the volcanic complex and even in some of the interior valleys, the reconnaissance observations of the Hayden and other early surveys were far too meager, and the present resurvey has thus far covered too small an area to afford solutions to many of the problems concerning the earlier geologic development of this most interesting field.

In view of this condition, no attempt will be made at this time to present a thorough review of San Juan geology, but in order that the significance of the observations made in the Ouray quadrangle may be more fully appreciated, an outline sketch of the geologic development of the region will be given. This outline is particularly applicable to the western part of the San Juan, for it is in the valleys of this portion, near the mountain front, that the best exposures of the older rocks may be found.

The Animas Valley, between Silverton and the vicinity of Durango, shows apparently a complete exposure of all formations of the San Juan, from the Archean to the Puerco formation of the Eocene, inclusive. Much of this section has now been studied in detail, but definite correlations can not yet be made between the older formations here seen and the isolated exposures reported from some other parts of the San Juan Mountains.

Ancient granites, gneisses, and schists are known in the Animas Valley on the south and in the Uncompahgre Plateau on the north. These rocks have usually been considered Archean, but the granites are probably younger than the great series of quartzites exhibited in the Needle Mountains and seen beneath the volcanics in the canyon of the Uncompahgre above Ouray, which have been referred to the pre-Cambrian age of sedimentation—the Algonkian. The Algonkian rocks have suffered great metamorphism and stand on edge or are greatly disturbed, and the relations of the isolated exposures to contemporaneous formations elsewhere are quite unknown. On the Hayden map these quartzites were called "Metamorphic Paleozoic." In this folio they are called the Uncompahgre formation.

Great continental movements of uplift, folding, and faulting, followed by enormous erosion, intervened between the deposition of the Algonkian sediments and the oldest Paleozoic formation. In the Animas Valley the Paleozoic section begins with a thin quartzite, less than 200 feet in thickness, which has been called the Ignacio quartzite and which, on scanty fossil evidence, has been referred to the Cambrian. Following this quartzite with apparent conformity come thin limestones and shaly strata, the latter characterized by casts of cubical salt crystals, and the whole having a thickness of less than 100 feet. These beds are distinguished as the Elbert formation and are assigned to the upper part of the Devonian, on the evidence of characteristic fish remains. Above them occurs, in conformity, a series of limestones with thin interstratified quartzites, 200 to 400 feet thick, known as the Ouray limestone, the lower and middle portions of which are characterized by a definite upper Devonian invertebrate fauna.

Although these thin formations have been followed for many miles up the Animas Valley, no indication of Silurian or Ordovician strata has been found there, nor any evidence of the stratigraphic gap which must exist if there are no beds of those ages in the section. In the Uncompahgre Valley near Ouray the Ignacio formation is lacking and the Elbert formation is not everywhere present, and at certain localities in the Silverton quadrangle the Ignacio is absent. These facts show that the seeming conformity in the section seen on the slopes of the Needle Mountains is misleading and that there is a stratigraphic break of great importance between the Ignacio and Elbert formations.

The extreme upper part of the Ouray limestone contains Mississippian (Lower Carboniferous) fossils at a few points observed in the Animas Valley. Above this limestone occurs a reddish calcareous shale, the Molas formation, containing many chert pebbles, and some of these cherts also carry a Mississippian fauna. Thin limestone layers in the shale contain Pennsylvanian (Upper Carboniferous) fossils, so that there is evidence of the stratigraphic break following the Ouray. The Molas shales have been found everywhere lying on the Ouray limestone with but slight unconformity. There is no known indication of the extent of the Mississippian formations that may have overlain the Ouray limestone, or of their character, except that the basal portion must have been a cherty limestone very similar to the Ouray and grading into it.

The red shales of the Molas constitute the oldest sediments of a great complex of sandstones and fossiliferous shales and limestones. belonging to the Pennsylvanian. Above the Molas these beds reach a total thickness of 2000 feet and have been named the Hermosa formation. They form the great scarp on the west side of the Animas Valley and other prominent topographic features on both southern and northern sides of the mountains.

Above the Hermosa strata appears an important series of reddish conglomerates, sandstones, marls, and thin limestones, in the upper part of which Triassic fossils occur. These rocks occupy a much larger area than the Hermosa in the zone adjacent to the mountains, and are conspicuous in the Animas, Dolores, San Miguel, and Uncompahgre valleys.

In the Rico Mountains a fauna that is related to the Permo-Pennsylvanian of the Mississippi Valley has been found in the lower portion of the reddish series, and this fossiliferous zone is called the Rico formation. It has also been identified in the Animas drainage, but its presence has not been recognized in the Uncompahgre Valley.

The nonfossiliferous portion of the reddish beds, which rests upon the Rico formation, and which is limited above by unconformable Triassic strata, has been called the Cutler formation. The name Dolores has been given to the Triassic portion, which is distinguished from underlying beds not only by its fossils but also by an unconformity.

Above the red Triassic beds come other formations that are correlated in general with the freshwater Jurassic of other parts of Colorado, and above these comes the Upper Cretaceous, from the Dakota to the uppermost coal-bearing member, the Laramie. Below Durango the post-Laramie formation made up of eruptive rock débris and known as the "Animas beds" rests upon the Laramie, and is in turn overlain by the Puerco and higher Eocene deposits.

Structurally, the most striking feature in the present attitude of the formations described, from the base of the Paleozoic upward, is their general southerly, westerly, or northerly dip away from a point in the west-central part of the San Juan Mountains. As seen in the section of the Animas Valley, all of these formations appear to be conformable. None of the various unconformities by overlap represented on the Hayden map as occurring in the area between Animas and San Miguel rivers exist within that territory. But two great orogenic disturbances, not indicated in the Animas section, are clearly shown on the northern slopes of the San Juan, and possibly one of them also on the southern side, not far east of Animas River. A pronounced unconformity exists between the Dolores and older beds in the Uncompahgre Valley, and the Dolores itself and all older sediments are wanting in the plateau traversed by the Gunnison and its southern tributaries east of Uncompahgre River, and the granites and gneisses are overlain by the probable equivalent of the La Plata sandstone, of assumed Jurassic age. A similar condition exists east of the Animas, in the drainage of Los Pinos and Piedra rivers, according to the Hayden map, but reconnaissance observations by A. C. Spencer in the Piedra Valley show that prevolcanic faulting and erosion may be, in part at least, the causes of the irregular relations in this district.

Other periods of uplift, erosion, or subsidence, in Paleozoic or Mesozoic time, are indicated by the apparent absence, or slight development, of Cambrian, Ordovician, and Silurian sediments, the presence of remnants of the Mississippian beds, the local development of the fossiliferous Triassic, and the absence of the marine Jurassic and of recognized equivalents of the great Lower Cretaceous section of Texas.

The geologic structure and constitution of the San Juan Mountains of to-day are mainly the result of dynamic forces which were intensely active during three great epochs of Tertiary time. With the first of these epochs the long cycle of Upper Cretaceous sedimentation was terminated by a continental uplift which was of unknown extent, but which may have been very great. To what extent the Cretaceous sea covered the San Juan Mountain area is not yet known, but the sediments of that sea are now exposed, dipping at generally low angles away from the mountains, on the northern, western, and southern sides. The Ouray, Telluride, and Silverton quadrangles contain evidence that the erosion of the epoch under discussion produced a plain of moderate relief across the oblique edges of the entire series of Mesozoic and Paleozoic formations. This plain seems to have bordered a higher land mass in the heart of the San Juan Mountain area, and to have extended a considerable distance—how far must ever remain a matter of hypothesis—to the north, west, and south. Upon this nearly plane surface, in the region where it is now exposed, the sandstones and conglomerates of the Telluride formation were deposited and had already attained a thickness of several hundred feet when the great epoch of volcanic activity began, producing the complex of rocks out of which the present San Juan Mountains have been sculptured. From exposures in the Telluride quadrangle it was inferred that the earliest volcanic tuffs were waterlaid deposits in the Telluride lake, but from the relations seen in the Silverton quadrangle it appears probable that the Telluride conglomerate is, in part, at least, a fluviatile formation and that there was, locally, valley erosion below the plane of that conglomerate before the volcanic cycle opened.

The volcanoes and fissure conduits of the San Juan, assisted, perhaps, by vents in adjacent regions, emitted an enormous amount of volcanic material, partly in fragmental form and partly in lava flows, and this material covers an area of certainly not less than 15,000 square miles to a depth of many thousand feet in the central portion.

The lowest member of the volcanic complex thus far discovered is a bedded deposit of andesitic rocks that reaches 2500 feet in observed thickness, called the San Juan tuff breccia or conglomerate. Its source is unknown. From the relations exposed in the Silverton quadrangle it is certain that the San Juan beds were in some places entirely removed by erosion before the eruptions of the next great volcanic epoch.

Succeeding the San Juan epoch came a time in which rhyolitic and andesitic magmas, together with others of intermediate composition, alternated, and built up the Silverton volcanic series of flows and tuffs to an aggregate thickness of 4000 feet or more. Above them lies the Potosi volcanic series, consisting predominantly of rhyolitic material, and observed to have a thickness of more than 1000 feet. During the Silverton epoch, and after it, there were intervals of great erosion.

The three series of lavas mentioned make up the greater part of the western San Juan Mountains. In the central San Juan the two earlier series become greatly diminished in thickness, and disappear under the Potosi and other lavas of various kinds not yet fully investigated, but known to include rhyolite, andesite, and basalt.

Most of the San Juan lavas came from sources that are unknown, but those of the Silverton series were in part poured out through fissure channels now identifiable on account of the dike masses which fill them. The bedded series are penetrated by several massive bodies of rocks that are in many places coarsely granular, such as gabbro, diorite, and monzonite, and it now seems probable that the intrusive bodies of diorite porphyry and the allied varieties found in the sedimentary beds adjacent to the San Juan Mountains on the west are also of later date than many of the surface lavas.

The volcanic eruptions in the San Juan area probably continued at intervals until late in Tertiary time, although only the products of the earlier outbursts are well known. Thus the volcanic period of building up was in part synchronous with the third great period already referred to—that of sculpturing by erosion—by which the mountains now existing have been produced. Within the volcanic area little evidence has been discovered by which the sequence of events can be correlated with the established divisions of Tertiary time. Deposits of Eocene age are known in the zone bordering the volcanic area, but they have not been found in direct contact with the lavas. Certain calcareous tuffs of the Silverton and Ouray quadrangles contain scanty plant and invertebrate remains, indicating that they were formed in Oligocene or early Miocene time. Although it may safely be assumed that the closer study of the San Juan will result in the recognition of different epochs of eruptive activity and of orogenic disturbance, the Tertiary history of this region may be summarized as a conflict between volcanic forces, which built a plateau by stupendous emissions of lava, and agencies of erosion, which removed the igneous material and carved deep canyons to the very base of the vast lava plateau. The volcanic forces were most effective in the earlier part of the period, when nearly the entire thickness of 5000 feet of volcanic rocks found in the western San Juan was accumulated, but the agents of degradation became prominent in the later part of the Tertiary and are still actively at work on the higher mountain masses.

Quantitatively, the work performed by the geologic agencies acting in this region in Cenozoic time has been very great, but the estimation of the post-Cretaceous disturbance, as well as the general deciphering of all earlier geological history, has been rendered very difficult by the mantle of volcanic rocks; and the original extent of this covering is left to speculation on account of the more recent erosion. The detailed examinations now in progress have thrown much light on these great problems. Thus, the Telluride conglomerate becomes of first importance in their solution, since its base presents the best evidence as to the post-Cretaceous erosion and its top forms the surface upon which the volcanics rested in the western part of the district.

The present elevation of this entire region above sea level is to be regarded as the result of numerous oscillatory movements of uplift or subsidence which have taken place since the close of the Cretaceous, affecting greater or smaller areas. A slight tilting of the Telluride formation in an easterly direction may be connected with the uplift of the extreme western San Juan region, leading to the great erosion which has caused such an abrupt face to the mountains in and about the Telluride quadrangle. The complex fault system existing in the Silverton quadrangle, which traverses all volcanic rocks in its course, is further evidence of Tertiary movements.

RELATIONS OF THE OURAY QUADRANGLE.

The situation of the Ouray quadrangle is such that it presents in epitome many of the principal features of topography and geology characterizing the broad area of the San Juan. It exhibits a rather typical section from the high and rugged mountains in its southern zone, a number of which rise above 13,000 feet, to the lowlands of the northwestern portion, about 6000 feet below. The common character of the intermediate slopes is illustrated, and the ridges bordering Cimarron Creek are remnants of a high plateau which, for many miles eastward, is more or less prominent between the mountain front and the Gunnison Canyon. The canyon and lower valley of the Uncompahgre are typical of the larger streams rising in the heart of the San Juan.

The deep dissection by Uncompahgre River and its tributaries has disclosed the character of the prevolcanic formations to a degree exceeded only in the Animas and other valleys traversing the Needle Mountains on the south side of the San Juan. Archean gneiss and schists are not revealed by the Uncompahgre, but in its canyon is exposed an excellent section of the pre-Cambrian quartzites and slates named after this river.

From the Uncompahgre (Algonkian) beds northward almost the entire Paleozoic and Mesozoic section is well exhibited within the Ouray quadrangle. The columnar section sheet gives a summary statement of the character and relations of the formations.

The broad domal structure, truncated by the surface upon which the Telluride conglomerate and the succeeding San Juan tuff rest, is well shown in the valley section. Of special interest is the unconformity below the Dolores (Triassic) formation, more clearly exhibited in the cliffs overlooking Ouray than at any other known locality.

The Tertiary geology of the San Juan, recorded in volcanic formations and their relations, is in large part well illustrated in the Ouray quadrangle. The San Juan tuff, the earliest and most extensive of the Tertiary formations, is represented in its maximum development. Only the upper portions of the Silverton volcanic series are to be found, but their relations to the San Juan, as seen in this area, furnish particularly clear evidence of the great erosion interval which followed the deposition of the San Juan tuff. The uppermost lavas, those of the Potosi volcanic series, are present in good but not extensive development.

The Pleistocene and Recent history of the region is also indicated in the Ouray quadrangle by especially well preserved and definite evidence in the shape of ancient terrace gravels, moraines, and landslide débris.

TOPOGRAPHY.

RELIEF.

The area included within the Ouray quadrangle has a considerable variety in its relief. The northwestern quarter consists of open valleys between which are rounded hills or low, flat-topped mesas, few of them more than 500 feet above the level of the valleys. On the east the land rises from Cow Creek for nearly 3000 feet to the foot of the high cliffs that form the face of Cimarron Ridge. This ridge is one of several that extend northward from the high mountains of this part of the San Juan group. Two such ridges, separating forks of Cimarron Creek and lying wholly or partly in the Ouray quadrangle, have been named Turret and Pinnacle ridges, from their characteristic topographic detail. These narrow and rugged divides are due to the deep dissection of a lava-capped plateau. A remnant of the plateau form is seen in Park Mesa, in the extreme northeast corner of the quadrangle.

In the western part of the area there is an abrupt rise from the lowlands to the summit called Baldy Peak, which forms the northwest extremity of a ridge separating the waters of Uncompahgre River and Cow Creek. A corresponding upland with a surface of moderate relief lies between the Uncompahgre and Coal Creek.

The highest mountains of the quadrangle are in its southern and southeastern parts, in an elevated region the greater part of which is above timber line and which is scored by deep canyons. In the heart of this mountainous area the town of Ouray is situated, in a park formed at the junction of several tributaries of Uncompahgre River. Many of the higher summits are over 13,000 feet in elevation. Wetterhorn Peak, near the eastern boundary of the quadrangle, is 14,000 feet high, and east, south, and west of the quadrangle many of the highest peaks of the San Juan Mountains are clustered.

DRAINAGE.

All the streams which drain the Ouray quadrangle belong to the Gunnison River system and their waters eventually find their way through Colorado River to the Gulf of California. In the quadrangle itself there are four drainage systems. North Fork of Henson Creek, in the extreme southeast corner, joins Henson Creek a few miles to the east, and the main stream enters Lake Fork of Gunnison River at Lake City. The three other systems, which drain more than nine-tenths of the whole area of the quadrangle, are those of Uncompahgre River, Cow Creek, and Cimarron Creek. The two forks of the Cimarron flow almost due north along the eastern border of the quadrangle from the two sides of Coxcomb Peak and join the main stream in a beautiful open valley in the extreme northeast.

Cow Creek, the longest individual stream, rises in the high open country known as the American Flat and flows diagonally across the entire quadrangle from southeast to northwest. In its upper portion the main stream and its chief branches, Difficulty and Wildhorse creeks, flow through unusually wild canyons bordered by bare rock walls that make the gorges inaccessible except at a very few points. Cow Creek canyon widens between Oban Creek and Ramshorn Ridge, and beyond the ridge the stream flows in a gradually opening valley, being in its lower portion bordered by fertile ranches. The creek joins Uncompahgre River less than half a mile beyond the northwest corner of the quadrangle.

Uncompahgre River rises in the high mountains of the Silverton quadrangle, and after passing through a narrow canyon, the lower portion of which is in the Ouray quadrangle, is joined by Canyon Creek. Below the town of Ouray the valley is narrow and hemmed in by high and steep cliffs almost to the mouth of Dexter Creek. From that point downstream the sides of the valley recede, leaving, north of Cutler Creek, a broad stretch of bottom land more than a mile wide, which is limited on the north by a great moraine that crosses the valley near the town of Ridgway, just beyond the boundaries of the quadrangle. For a distance of little more than a mile the river flows outside the quadrangle, but reenters at the point where it cuts through the moraine and thence flows northward, leaving the quadrangle again on the west within a mile and a half of the northern boundary.

CLIMATIC CONDITIONS.

The variation in climatic conditions in different parts of the quadrangle is in direct relation to the topography and relief. The higher mountain region has an abundant rainfall and in consequence supports a vigorous forest growth of spruce and aspen. The lowland of the northwest corner of the quadrangle gets little rain in comparison with the mountain areas and really belongs to the region of semiarid plateaus stretching off to the west and northwest. Although the land is extremely fertile when irrigated, sagebrush, piñon, and cedar represent the normal vegetation. Between these extremes of wet and dry is a zone of moderate rainfall characterized by scrub oak, which clothes the middle slopes in an almost impenetrable tangle.

DESCRIPTIVE GEOLOGY.

SEDIMENTARY FORMATIONS.

ALGONKIAN SYSTEM.

NEEDLE MOUNTAINS GROUP.

UNCOMPAHGRE FORMATION.

Name.—The name Uncompahgre formation was proposed in the Silverton folio for a great succession of supposed Algonkian quartzites, slates, and subordinate conglomerates represented in the canyon of the Uncompahgre by several thousand feet of upturned strata. The exposures of these beds begin near Ouray and extend for a few miles southward in the Silverton quadrangle, but neither top nor bottom of the larger conformable series to which the visible section belongs is there shown. The name was proposed for the entire assemblage of pre-Cambrian conformable quartzites and slates of which extensive exposures exist also in the Needle Mountains. During the survey of that area it was found that the main quartzites and slates of the Needle Mountains were like those of the Uncompahgre section, but from structural complexities the thickness represented was less, and, as in the Uncompahgre Canyon, the upper and lower parts were not seen. At the southeastern base of the Needle Mountains, in Vallecito Canyon, however, a heavy conglomerate was discovered and traced eastward, to a point where it was found in such relations with the Uncompahgre quartzites and slates that it appeared to be unquestionably the lower part of the group. To this conglomerate the formation name Vallecito was given and to the group which includes it and the Uncompahgre, together with higher members that may hereafter be recognized, the name Needle Mountains group was applied.

The total thickness of the Needle Mountains group is unknown. Two thousand feet or more of the basal conglomerate member occur a few miles east of Vallecito Creek, in the vicinity of Emerald Lake, on Lake Fork of Pine River, and 8500 feet must be allowed for the section of quartzites and slates exposed in the Uncompahgre Canyon. The complicated folding and shearing within the formation indicated in the Needle Mountains area and the complete unconformity with overlying beds, indicating a long period of deformation and erosion preceding the deposition of the earliest fossiliferous rocks, make it impossible to estimate the original thickness of the Needle Mountains group or to recognize an upper limit of the section.

Description.—The rocks of the Uncompahgre formation exposed in the Ouray and adjoining Silverton quadrangles consist principally of quartzite, with bands, in many places hundreds of feet in thickness, of argillaceous rocks in most of which a secondary slaty cleavage has been developed. Both kinds of rock are well bedded, the quartzites, from their greater hardness, preserving original structures better than the slates. Ripple-marked surfaces are common and have been the means of determining the relative position of the upper and lower parts of the formation, which is not at first evident on account of the nearly vertical attitude of the beds.

The quartzites are very thoroughly indurated and consist of nearly pure silica in the lighter colored varieties, with very small amounts of sericite or chlorite. Darker varieties show a little finely divided magnetite or hematite and rarely minute flakes of biotite. The colors of the quartzite vary from pure milk white through blues, grays, and pinks of delicate shades to dull browns or blacks of the less pure kinds. Microscopical examination of thin sections has shown well-defined systems of parallel cleavages in the grains of quartz constituting the rock, the cleavage cracks being filled with sericite.

The argillaceous members have been much more affected by the dynamic metamorphism of the region, and most of them are now slates or schists. Some are extremely dense, fine-grained argillites which under the microscope appear to be made up largely of quartz, with sericite in minute needles all having practically the same orientation. Others are coarser and less completely metamorphosed and contain much "earthy" impurity that remains dark between crossed nicols. A few contain andalusite or staurolite in impure crystals. The prevailing colors are dark greens, browns, and purples, although some soft, shaly bands may be almost jet black. Local crumpling is not uncommon in portions of the thin-bedded argillites, but in general the beds are parallel with the quartzites and dip at a high angle to the north.

Distribution.—The quartzites and slates of the Uncompahgre formation are exposed on both sides of Uncompahgre River for about a mile and a half north of the southern boundary of the quadrangle. They are limited on the north by a fault which brings them into contact with Paleozoic sediments; on the east they are covered by the San Juan tuff and on the west by the oldest Paleozoic sediments. The formation is exposed farther south, in the Silverton quadrangle, for nearly 2 miles. The hard quartzites and the slates protected by them form the precipitous walls of a canyon of unusual grandeur, through which Uncompahgre River flows to the outskirts of the town of Ouray.

CAMBRIAN SYSTEM.

IGNACIO QUARTZITE.

The lowest lithologic division of the Paleozoic section known in the San Juan Mountains is made up of quartzites, and varies in thickness, in the Animas Valley, where its best development has thus far been found, from a few feet up to 200 feet. This formation is fully described in the Silverton and Needle Mountains folios and was named the Ignacio quartzite from its typical occurrence near Ignacio Lakes, in the Animas Valley. From layers near the middle of these quartzites a single generically determinable shell has been found, identified by Charles D. Walcott as *Obolus* sp.?, related to forms found in the middle or upper Cambrian at various localities in the western United States. Fragments of shells, belonging, it is believed by Walcott, to the same genus, were found in the only known occurrence of the formation in the Ouray quadrangle.

The Ignacio quartzite is not present in the Paleozoic section south of Ouray, where the lowest known beds are the Elbert shales, resting directly upon the Algonkian quartzites. Its absence in this region may be due to nondeposition or to erosion preceding the Elbert. The only locality at which the Ignacio is known to occur in the Ouray quadrangle is on Cow Creek, a little north of Oban Creek, where there is a small area occupied by Ouray limestone which is bounded by faults on all sides. Through this limestone a number of prospecting shafts have been sunk, and in one at least Ignacio quartzite was encountered. The shaft is now closed by rubbish, but material lithologically like the Ignacio quartzite was found on the dump, apparently obtained from the bottom of the shaft. That this material indicates the presence of the Ignacio is considered certain from the characteristic trail markings and fragments of the distinctive shell *Obolus*. The significance of this occurrence, both structural and stratigraphic, is discussed under the the heading "Structure."

DEVONIAN SYSTEM.

INTRODUCTION.

The presence of Devonian sediments in the San Juan region was established in 1874 through a collection of fossils made by F. M. Endlich, of the Hayden Survey. The formation containing the invertebrate fauna discovered by Endlich has been named the Ouray limestone, and the beds immediately below it, containing an upper Devonian fish fauna, have been distinguished as the Elbert formation.

ELBERT FORMATION.

Name and definition.—The name Elbert formation has been applied to a succession of calcareous shales, thin limestones, and local quartzite beds, aggregating less than 100 feet in thickness, as a rule, and characterized by scanty remains of ganoid fishes. On the southern side of the San Juan Mountains these strata generally rest upon the Ignacio quartzite, of middle or upper Cambrian age, although a great stratigraphic break comes between them; above they are covered conformably by the Ouray limestone. The name is derived from Elbert Creek, a western tributary of Animas River that drains the Ignacio Lakes and flows for some miles upon a broad bench where all the lower Paleozoic formations are well exposed.

Lithologic character.—The formation is composed mainly of calcareous shales and thin, sandy limestones varying in details of development from place to place. The beds are drab, buff, or yellowish in color. The shaly layers break up readily on exposure, so that outcrops are obscured by the resulting scales and thin plates. Quartzites are present but are everywhere very thin and subordinate to the calcareous or shaly portion. The shaly beds are in many places characterized by pseudomorphous casts after salt crystals. The crystals were in general more or less clearly skeleton cubes with sunken faces, ranging in size up to an inch or more in diameter. So abundant are these casts that they may be found at nearly every outcrop, but they are more perfect and of larger size in some localities than in others.

As may be seen from the accompanying section, the occurrence at Ouray is not characteristic. The total thickness does not exceed 40 feet; the beds are more sandy and contain a greater number of thin quartzite layers than usual; moreover, the casts of salt crystals, so typical of the shaly members in the Animas Valley, are rarely seen in them.

Section of Elbert formation on west side of Uncompahgre Canyon, 1 mile southeast of Canyon Creek.

	Ft.	in.
Top.		
11. Sandstone, buff, in general fine grained, but grading within a few feet into a gritty quartzite; bands are not uniform in thickness nor continuous for considerable distances; lenses of calcareous pink shale or gnarly limestone (6 to 18 inches thick) occur near the top under a fine-grained, massive, buff sandstone	15	0
10. Shale, calcareous, and thin-bedded limestone, buff and pink; much of the limestone in lenses and as a rule not more than 3 or 4 inches thick except near the top, where it becomes nodular and gnarly and more lenticular	12	0
9. Quartzite, bluish gray, gritty	0	8
8. Shale and sandstone, thin bedded, buff	1	0
7. Quartzite, gray, conglomeratic and gritty	1	0
6. Shale and very thin bedded sandstone, buff	1	6
5. Sandstone, pink to green	0	10
4. Sandstone, buff to greenish, fine grained, shaly near top	1	6
3. Shale, red, sandy	0	6
2. Limestone, siliceous and not sharply separated from quartzite below; shaly partings (red) above; general color greenish; redder and sandy near top	3	0
1. Quartzite, gritty and conglomeratic, greenish	1	0
Upturned edges of Uncompahgre slates.		
	38	0

Age.—Meager remains of ganoid fishes found in association with the salt-cast shales in the Animas Valley region have been characterized by C. R. Eastman as belonging to a distinct upper Devonian fauna, allied to that of the Catskill and Chemung groups of New York, and a correlation, on fossil evidence, has been suggested between the Elbert formation and the "Parting quartzite" of the Aspen district. *Bothriolepis* and *Holoptychius* are the generic forms most abundant.[1] No other beds that are lithologically like the Elbert have been found in Colorado. For a more complete discussion the reader is referred to the Needle Mountains folio and to special papers.

[1] Cross, W., and Eastman, C. R., Am. Jour. Sci., 4th ser., vol. 18, October, 1904.

Distribution.—The Elbert occurs at only one locality in the Ouray quadrangle, being well exposed at a number of points below the cliff of Ouray limestone that overlooks the Uncompahgre Canyon south of Ouray. To the north it is limited at the box canyon of Canyon Creek by an east-west fault, and to the south it thins out and within a short distance disappears, leaving the Ouray formation resting upon the Algonkian sediments. It is probably present between the Ouray and Ignacio in the Cow Creek locality already mentioned, but the rocks were not recognized among the materials removed from the shaft.

OURAY LIMESTONE.

Name and age.—Since the Ouray limestone has been described in the Silverton and Needle Mountains folios and in special papers it is unnecessary to enter here into many details of age and correlation that are discussed at length elsewhere. The name was first given to the formation from its typical occurrence south of the town of Ouray, and was applied to the Devonian limestone member of the pre-Carboniferous Paleozoic. The subsequent discovery of Mississippian fossils in the upper portion of this limestone necessitated a change in definition. Since it is impossible to draw a line between the two portions, the Ouray becomes preeminently a lithologic unit transgressing the faunal boundary between the Devonian and Carboniferous systems.

Lithologic character.—The Ouray limestone as known at present has a thickness varying from 100 to 250 feet. The upper and major part of the formation is massive limestone, either in one bed or with such thin intercalated shales that the tendency of the limestone to cause mesas, benches, and prominent cliffs as characteristic topographic forms is everywhere notable. Below the more massive portion a third or less of the section is made up of well-bedded limestone 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 chert concretions, free from fossils, are common at a horizon near the base. The lowest stratum is characterized in most places by crinoid stems and rarely a cup coral.

The greater part of the formation is dense, compact limestone, but portions of the upper ledge are coarsely crystalline. In general, the rock is nearly white, straw yellow, or buff, with local pinkish tones. 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 Hermosa is marked, layers of such character occurring only near the base of the Ouray. No change in character of the limestone occurs toward the top unless a prevalence of coarse-grained, rotten beds, observed locally and belonging to the Carboniferous portion, in some places at least, be regarded as characteristic. The conditions of sedimentation seem to have remained the same and deposition seems to have been continuous from Devonian into Carboniferous time.

Fauna.—The Devonian invertebrate fauna of the Ouray limestone occurs at horizons ranging from one near the base of the formation to one which in many places is not far below the top of the upper massive ledge. The greater number of species occur in this upper portion, but many of them range to a horizon within a few feet of the base. Fossils have been obtained at Ouray and at several localities in the Needle Mountains, Engineer Mountain, and Durango quadrangles, as well as at the point where Endlich first found a few characteristic species a short distance south of the Needle Mountains quadrangle.

The invertebrate fauna of the Devonian portion of the Ouray limestone has been fully described by G. H. Girty and compared with similar faunas hitherto collected in Colorado, notably in the Elk Mountains, at Glenwood Springs on Grand River, near the head of White River, and on East Monarch Mountain, Chaffee County. Full correlations 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.

Among the most typical Devonian species obtained from the Ouray limestone are the following:

Schizophoria striatula.	Camarotœchia endlichi.
Schuchertella chemungensis.	Camarotœchia contracta.
Productella semiglobosa.	Paracyclas sp.
Productella subalata?	Naticopsis gigantea.
Athyris coloradoensis.	Naticopsis? (Isonema) humilis.
Spirifer coniculus.	Straparollus clymenioides?
Spirifer disjunctus var. animasensis.	Orthoceras sp.

Concerning the general relations of this fauna Girty states that "In general the Devonian fauna of the Ouray belongs to Upper Devonian time. It is but distantly related to the Devonian faunas of upper New York, and its relation with those of the Mississippi Valley, or even with other known western Devonian faunas, is not close."

The Carboniferous portion of the Ouray has nowhere been found to be distinguishable lithologically from the Devonian. Its existence on the southern slope of the San Juan was detected through the presence of lower Carboniferous invertebrate fossils in the chert pebbles of the succeeding formation. During the investigations as to the origin of these pebbles G. H. Girty found that some of the fossils of the chert pebbles occurred also in the uppermost strata of the massive limestone hitherto supposed to belong wholly to the Devonian.

Among the fossils from the upper part of the Ouray are the following:

Rhodocrinus sp.	Spirifer centronatus.
Platycrinus sp.	Spirifer peculiaris?
Rhipidomella pulchra.	Spiriferina solidirostris?
Schuchertella inæqualis.	Eumetria marcyi?
Productus semireticulatus var.	Camarotœchia metallica.
	Myalina keokuk.
Productus lævicosta.	Phillipsia peroccidens.

The localities at which the Carboniferous forms have been found in the limestone are few, mainly near Cascade Creek, in the Engineer Mountain quadrangle. Chert pebbles have been found in place in these upper strata but rarely, and this fact, together with their abundance in the succeeding Molas conglomerate, shows that an interval of erosion followed the formation of the limestone. In the area thus far studied this erosion effected the removal of nearly the whole of the chert-bearing, Carboniferous portion and an unknown amount of the subjacent massive rock, but nowhere cut away enough of the Ouray to make angular unconformity noticeable except in small detail. At no known point has the erosion penetrated to the horizon of Devonian fossils in the massive limestone. Inasmuch as neither this horizon nor that of the Mississippian forms is recognizable in many sections the question as to how much, if any, of the Ouray should, in such cases, be referred to the Carboniferous is a matter of uncertainty.

Distribution.—The Ouray limestone occurs at two localities in the quadrangle, directly south of Ouray and in Cow Creek north of Oban Creek. The exposures near the town are of the upper, massive limestone and have a steep dip to the north, which carries them beneath the alluvial fan of Portland Creek and the landslide débris of The Amphitheater. On the south they are limited by a fault contact with the Algonkian quartzites. The best exposures of the whole formation are found west of the Uncompahgre, extending southeastward from the box canyon of Canyon Creek. The beds rise from the east-west fault at the box canyon for nearly a thousand feet to the broad, flat bench on the west side of the Uncompahgre Canyon, at the edge of which they form, with the Elbert beneath them, an abrupt cliff 200 feet or more in height. Half a mile south of the boundary of the quadrangle the Elbert shales disappear and the Ouray rests directly upon the upturned edges of the Algonkian.

The occurrence in Cow Creek is peculiar and of greater structural than stratigraphic importance. The exposed part lies almost wholly on the east side of the stream, and belongs to the upper, massive member of the formation. It is entirely surrounded by landslide débris and its relation to the other rocks is obscure. This locality is discussed in detail under the heading "Structural geology."

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

UPPER PORTION OF OURAY LIMESTONE.

As has been shown in describing the Ouray limestone, it is known that a Mississippian (Lower Carboniferous) fauna occurs in the upper part of that formation in certain localities, separated from the uppermost Devonian fossiliferous stratum by about 50 to 75 feet of massive limestone in which no fossils have thus far been discovered. The erosion in the interval following Mississippian sedimentation removed those strata completely over large areas. As neither the upper Devonian nor the basal Carboniferous is everywhere fossiliferous, it is impossible in many places to decide whether the upper portion of the Ouray limestone is Carboniferous or not.

From the great quantity of Carboniferous chert nodules in the succeeding formation it must be assumed that above the known horizons of the Ouray there once existed in this region a considerable thickness of chert-bearing limestone of Mississipian age. It seems not unlikely that somewhere on the slopes of the San Juan Mountains notable remnants of these beds may be found.

In the Ouray quadrangle a short distance northwest of the Mineral Farm mine, near the upper road which leads up Canyon Creek, there is a marked local unconformity between the Ouray limestone and the Molas formation. The locality is very near the base of the Hermosa formation and the Ouray appears to rise in a sharp ridge through the Molas, which rests with angular unconformity against the flanks of the ridge. The limestone contains many concretionary chert nodules similar to those that occur as bowlders or pebbles in the Molas, and a poorly preserved *Spirifer* (believed to be a Mississipian form) was found. The limestone appears more sandy or siliceous than the familiar Ouray, near the top, generally recognized in this region. It is believed that this occurrence represents a remnant of the Mississippian portion of the Ouray, although sufficient fossil evidence to prove it is lacking.

PENNSYLVANIAN SERIES.

MOLAS FORMATION.

Name and definition.—The name Molas formation was proposed in the Silverton folio for the lowest Pennsylvanian formation distinguished in the Animas Valley and adjacent regions. The name is derived from Molas Lake, which lies on the bench west of the Animas Canyon and just south of the Silverton quadrangle, at an altitude of 10,500 feet. The lake basin is partly excavated in the Molas beds and they are well exposed for some distance south of the lake.

The Molas formation is distinguished as a cartographic unit on lithologic grounds, being a well-characterized element in the Carboniferous section, and because it records in certain peculiarities of its sediments important events of the preceding interval of erosion, including the almost total destruction of a Mississippian formation. There may also be a further reason for separating the Molas and Hermosa formations in certain observed faunal differences, which are, however, not yet sufficiently established to warrant laying much stress on them.

The Molas formation was defined as a thin series of reddish calcareous shales and sandstones, with many pebbles of chert and some of limestone, quartzite, and other rocks, and with thin fossiliferous limestone lenses, the fossils showing intimate relations to those of the lower Hermosa limestone. It occurs immediately below the Hermosa formation and rests upon a surface of erosion. It represents the earliest sediments of Pennsylvanian Carboniferous in this region.

Lithologic character.—The Molas formation is especially characterized by its deep-red, friable, sandy strata, which are variably calcareous and in many places shaly. As a rule they are not very distinctly bedded, and they disintegrate so rapidly on weathering that good exposures are rare. In the lower part of the formation dark chert nodules abound, forming at numerous points a large part of flat lentils or discontinuous layers. A complete section of the formation is exposed on the north side of Canyon Creek near its junction with Uncompahgre River, and, although the formation is not so thick here as it is on the southern slopes of the San Juan Mountains, its development is characteristic. This section is limited above by a coarse grit or conglomerate that is assumed to be the basal stratum of the Hermosa, and at the bottom the Molas is sharply in contact with an erosion surface of the Ouray limestone.

Section of Molas formation on north side of Canyon Creek, 100 feet above junction with Uncompahgre River.

	Top.	Feet.
14.	Conglomerate, red and filled with chert fragments, becoming finer grained above until it resembles a gritty red quartzite	4
13.	Sandstone and conglomerate with shaly partings, red	3
12.	Shale, red	10
11.	Conglomerate, chert fragments in red cement	3
10.	Shale, red	2
9.	Conglomerate, red, pebbles smaller than at lower horizons and cement more abundant	1
8.	Shale, red, with a few limestone and chert pebbles; near the middle, mottled light yellow	5
7.	Conglomerate, dark red, containing chert and quartzite pebbles in a reddish calcareous cement	1 to 1½
6.	Shale, red, sandy, and with no pebbles except for a thin layer near the base	3
5.	Conglomerate, light yellow or straw color, with black cherts embedded in a calcareous cement, less conglomeratic near top	2
4.	Shale, red and calcareous, containing many chert and some limestone pebbles	5
3.	Conglomerate, largely made up of chert pebbles with a varying amount of reddish cementing material somewhat resembling the shale below; in part more like a fine red grit	4
2.	Shale, gnarly, reddish	3
1.	Conglomerate, siliceous, dark red or purple, containing numerous chert fragments	2
		48½

The base rests upon Ouray limestone, massive and somewhat sandy, seeming to belong to a higher horizon than that commonly seen. It is in places traversed by many crevices in which reddish shaly material has been deposited.

Age and stratigraphic relations.—Many of the chert fragments in the lower part of the formation carry a Mississippian invertebrate fauna, the derivation of which from the Ouray limestone has been discussed. In the uppermost part of the formation, at a single locality in the Needle Mountains quadrangle, some thin limestone beds are intercalated between sandstones, and these contain a Pennsylvanian fauna which, according to Girty, is "related to that of the Hermosa formation but contains no species in common with the Ouray limestone. Some points of individuality distinguish the Molas fauna from that of the Hermosa, but it can not be conjectured how far this would be borne out by full collections." The species obtained from the Molas, as determined by Girty, are the following:

Archæocidaris triplex.	Spirifer boonensis?
Rhombopora lepidodendroides.	Composita subtilita.
Rhipidomella pecosi.	Myalina perniformis.

Wherever the Molas formation has been observed it rests upon a surface due to the erosion by which the Mississippian portion of the Ouray limestone was almost completely removed. Although it has not been observed to lie upon any formation other than the Ouray limestone, the nature of the case permits the supposition that somewhere in the region adjacent to the San Juan Mountains it must transgress the lower Paleozoic formations and rest upon Algonkian quartzites, granite, or schist.

The Molas and Hermosa seem to be thoroughly conformable and probably the former is the product of the first epoch within the long period of Pennsylvanian sedimentation. The red color of its sediments and the other peculiarities mentioned characterize it.

Occurrence.—The Molas formation is present south of the town of Ouray at a number of localities, although from its soft, friable nature little of it is well preserved. Remnants may be seen clinging to the steeply dipping surface of the Ouray at the edge of the town by the wagon road leading to Uncompahgre Canyon. The best exposures are just below the box canyon of Canyon Creek, and portions of the lower chert conglomerates may be seen in the vicinity of the Mineral Farm mine. The broad bench formed by the Ouray limestone between Uncompahgre Canyon and the steeper slopes of the Hermosa indicates the former presence of these soft beds. They occur also on the south side of The Amphitheater, and the characteristic red stain of clay filling cracks in the limestone may be seen at nearly all places where the old erosion surface of the Ouray is exposed.

HERMOSA FORMATION.

Name and definition.—The Hermosa formation includes the series of alternating limestones, shales, and sandstones, having a maximum thickness of 2000 feet, which occurs on the northern and southern flanks of the San Juan Mountains. As originally defined, its lower and upper limits were marked by the Molas and Rico formations, respectively. In the Ouray district no beds carrying a typical Rico (Permo-Pennsylvanian) fauna have been found, and the Hermosa is here apparently followed by the Cutler red beds, of supposed Permian age. The name was derived from Hermosa Creek, a tributary of Animas River, which traverses a large area of these rocks in the Engineer Mountain quadrangle.

Lithologic character.—In the Animas Valley, near the mouth of Hermosa Creek, the lowest third of the complex is made up of green sandstones and shales with some gypsiferous shales, and the rest of the formation shows limestone layers distributed throughout. Along the great scarp facing the Animas, which extends for 10 miles in the Engineer Mountain quadrangle, the limestones become more and more prominent and certain beds are very thick.

In the Rico district the massive limestones are prominent only in the middle portion of the formation, the upper part consisting mainly of black and gray shales alternating with green grits and sandstones and with a few limestone layers.

At Ouray the character of the formation is again different; the lower 300 feet consist of relatively thin, alternating beds of sandstone, shale, and a few gnarly fossiliferous limestones. The prevailing colors are dark greens, grays, and buffs, with here and there reddish shales and pinkish grits. In the Animas Valley section the actual base of the formation is marked by a massive and persistent limestone, but at Ouray this is not present and the section begins with a rather coarse quartzite and chert conglomerate, the pebbles of which lie in a gray gritty cement. The line between the Molas and Hermosa is not sharp and has been drawn on purely lithologic grounds, the Hermosa beginning where the red marls and shales of the Molas end. The upper and greater part of the Hermosa consists of pink massive grits and sandstones, red sandy shales, and thin, gnarly fossiliferous limestones. The massive sandstones, which are coarse and gritty, vary from 50 to 75 feet in thickness and are separated from one another by the red shales and thin-bedded sandstones or calcareous layers. The heavy limestone members so characteristic of the formation in the southwestern San Juan are here altogether lacking. Individual strata change laterally both in character and in thickness and under these conditions it has been found impracticable to subdivide the series into smaller lithologic units for purposes of mapping.

The Rico formation, which succeeds the Hermosa on the southwestern side of the San Juan Mountains, has not been identified in the Ouray section. Lithologically the uppermost limestone of the Hermosa resembles a bed in the Rico formation at the type locality in the Rico Mountains, but the scanty fauna which this limestone contains has been pronounced by Girty to be of the Hermosa type and the highest fossiliferous strata are immediately followed by characteristic red beds of the Cutler, which contain no fossils.

Fauna and correlation.—Girty has summarized his views as to the fauna and correlation of the formation as follows:

> The fauna of the Hermosa formation is distinctly Pennsylvanian (Upper Carboniferous) in age.
>
> If the formation be divided into three portions, especially as the division was carried out in the Rico region, the fauna of each is to a certain extent characteristic. That of the lower division consists almost altogether of brachiopods. In the middle division a number of gasteropods are introduced, and in the upper, in addition to brachiopods and gasteropods surviving from the middle division, a considerable force of pelecypods appears. The brachiopods remain nearly constant in number, but form a diminishing proportion of the entire fauna. The brachiopodous representation remains fairly uniform, though some changes occur in species and in abundance. The lower bed especially is characterized in many places by *Productus gallatinensis*, *Productus inflatus*, and a large variety of *Spirifer* of the *rockymontanus* type.
>
> The general characteristic of the Hermosa fauna may be illustrated by the following partial list of species:

Triticites secalicus.	Meekella striaticostata.
Chætetes milleporaceus.	Chonetes mesolobus.
Rhombopora lepidodendroides.	Productus semireticulatus var. hermosanus.
Prismopora serrata.	Productus cora.
Chainodictyon laxum.	Productus punctatus.
Orthothetes crassus.	Productus nebraskensis.
Marginifera wabashensis var.	Aviculipinna? peracuta.
Spirifer rockymontanus.	Allerisma terminale.
Spirifer cameratus.	Edmondia subtruncata,
Squamularia perplexa.	Euomphalus catilloides.
Spiriferina campestris.	Bellerophon crassus.
Composita subtilita.	Patellostium montfortianum.
Acanthopecten carboniferus.	Euphemus nodocarinatus.
Myalina subquadrata.	Phillipsia major.

> The fauna of the Hermosa formation occurs also in the Weber limestone and lower Maroon formation of the Crested Butte district, and in the Weber formation of the Tenmile and Leadville districts. From this fact and the similarity in stratigraphic occurrence a correlation of these formations appears to be justified. The Hermosa fauna represents early Pennsylvanian sedimentation, and it is probably older than the "Upper Coal Measures" faunas of the Kansas and Nebraska sections.

Distribution.—The immediate vicinity of Ouray is the only place in the quadrangle where the Hermosa occurs. In a distance of less than a mile the formation rises from below the level of the Uncompahgre Valley to a height of more than a thousand feet and forms the greater part of the precipitous cliffs west and northeast of the town of Ouray. East of the river the Hermosa is not exposed south of the north wall of The Amphitheater except for one small patch between the Molas and the San Juan tuff south of Portland Creek. West of the Uncompahgre the Hermosa beds, where not obscured by landslide débris, may be traced southward along Canyon Creek, and above the Ouray limestone bench west of the Uncompahgre Canyon to the southern boundary of the quadrangle.

PERMIAN (?) SERIES.

CUTLER FORMATION.

Name and definition.—The name Cutler formation was proposed in the Silverton folio for the 2000 feet or more of red shales, sandstones, grits, and coarse conglomerates forming a part of the assemblage familiarly known in many parts of the West as the "Red Beds." At Ouray, where the necessity of distinguishing the formation was first apparent, it follows the Hermosa with apparent conformity, but on the southern and western slopes of the San Juan the Rico formation, of Permo-Pennsylvanian age, intervenes between the Cutler and the Hermosa. The full original thickness of the formation is perhaps unknown as yet, since it is evident that the stratigraphic break between the Cutler and Dolores formations, marked at Ouray by sharp angular unconformity, may be present elsewhere, and that an indefinite upper portion of the Cutler may have been removed over a large area. In the earlier reports on the San Juan region the present Cutler formation was provisionally considered as a lower unfossiliferous part of the Dolores and was supposed to be of Triassic age. The discovery at Ouray, however, of the unconformity at the base of the lowest known fossiliferous Triassic showed that this grouping was incorrect, and the Cutler, in the entire absence of fossil evidence, is now regarded as of probable Permian age, succeeding, as it does without stratigraphic break, the Permo-Pennsylvanian Rico formation in the Animas Valley and Rico Mountains sections. For a fuller discussion the reader is referred to a recently published paper.[1] The name of the formation is derived from Cutler Creek, a tributary of Uncompahgre River about 4 miles north of the town of Ouray. In this region the Cutler formation is well exposed and very characteristic in development.

Description.—The Cutler formation, so far as it has been observed in the San Juan Mountains, is composed of essentially shallow-water or fluviatile deposits whose materials were not transported far from their sources. A very great majority of the beds are arenaceous; a few are coarsely conglomeratic, and a fair proportion of the whole consists of sandy and in places calcareous shales. At no point in the section do beds of one sort greatly predominate, an alternation of sandstones and shales being the rule. Ripple-marked surfaces and rain-drop impressions are often seen; cross-bedding is a feature of many of the sandstone members, and abrupt changes in the character of the beds are more common than persistency for even short distances.

The sandstones are in few places more than 20 feet in thickness and generally less. Some of the coarser grits are pink and purplish, but most of them are a clear brick-red or indian red. The

[1] Cross, W., and Howe, E , The Red Beds of southwestern Colorado: Bull. Geol. Soc. America, vol. 16, 1905, pp. 447–498.

greatest variety of textures can be found, the rocks ranging from those of extremely fine grain, hardly to be distinguished from the shales, through coarser and coarser sandstones and grits to some of the finer conglomerates. Cross-bedding in some of the sandstones is very striking on account of the alternation of lighter and darker layers.

In the Ouray region several very coarse, massive conglomerates occur in the upper portion of the formation. They are purplish and of a darker color than the other beds and are at once remarkable on account of their coarse texture. In many localities the relative amounts of bowlders and matrix vary greatly in short distances, but ordinarily their proportions are about equal, although an abrupt increase of the coarse materials may be accompanied by a reduction of the cementing material to a minimum. The pebbles and bowlders are well rounded and in general not more than six inches in diameter; they represent most of the older rocks of the San Juan, the greater number being pre-Cambrian granites, schists, greenstones, or quartzites.

The shales, like the sandstones, are bright red. They are in places calcareous and almost invariably sandy and, as has been said, it is not everywhere possible to differentiate them from the fine-grained, argillaceous sandstones. Some of the shales are fairly compact and well bedded and where protected by massive sandstones above do not weather so easily as the shales of the Hermosa; more commonly, however, they are soft and friable and occur in beds a few feet thick between the sandstones, or as thin partings in the sandstones themselves. For this reason, and notwithstanding their abundance in the section, the sandstone escarpments are not obscured and the formation as a whole is a resistant one in which cliff outcrops are common.

The most striking feature of the Cutler formation is the bright vermilion or brick-red color which characterizes all of its beds.

Distribution.—From the canyon of the Uncompahgre north of Ouray the red Cutler beds extend down the valley for 6 or 7 miles to a point near the mouth of Coal Creek, where the prevailing northwesterly dip carries them below the valley floor. Except for a few places on the west side of the river, where considerable glacial drift covers the hillsides, the formation is well exposed. The sharp fold that crosses the Uncompahgre in the vicinity of Bridalveil Creek (fig. 9, illustration sheet) lifts the Cutler beds so high on the east side of the river that they are cut off by the unconformable Dolores formation. On the west side of the river south of the fold the beds of the Cutler are preserved and, gradually assuming apparently conformable relations with the Dolores, may be traced past Oak Creek almost to the southern boundary of the quadrangle. On Cow Creek the Cutler occurs, more or less obscured by landslide débris, between Oban Creek and the porphyry of Ramshorn Ridge. The best exposures of this region are in the canyon of Red Creek, which has been excavated for nearly 2 miles in the "Red Beds." Here the La Plata sandstone rests upon the Cutler, some of which, together with the Dolores, it has transgressed, through the unconformity at its base.

TRIASSIC SYSTEM.

DOLORES FORMATION.

Name and definition.—The Dolores formation was originally defined in the Telluride folio as embracing the Triassic strata of southwestern Colorado and adjacent territory, the name being derived from Dolores River, in the valley of which the formation occurs. Triassic fossils were found only in the upper part of the section, but a great thickness of underlying "Red Beds," now known as the Cutler formation, was included as a part of the Dolores formation. At Ouray an unconformity occurs at the base of the lowest fossiliferous Triassic stratum, and on account of this the older "Red Beds" have been separated from the Dolores and described as the Cutler formation. The name Dolores will be applied, as heretofore, to the Triassic strata embracing the fossiliferous conglomerates and overlying beds. The lower limit of the formation is marked by a stratigraphic break, but as yet this has been observed only at Ouray, where a sharp angular unconformity causes the Dolores to cross the inclined and beveled strata of the entire Cutler formation and to rest upon similarly inclined beds of the Hermosa. Elsewhere in the San Juan Mountains and in near-by regions that have been examined the Dolores rests with apparent conformity upon the Cutler. The Dolores is succeeded above by the La Plata sandstone, but is separated from it by another stratigraphic break that is not everywhere evident.

Description.—In the Ouray quadrangle the remnant of the Dolores formation does not exceed 100 feet in thickness. Several limestone conglomerates occur near the base, separated by fine-grained sandstones or shales. The rest of the formation consists of marls, sandy shales, and fine-grained sandstones, all of a bright vermilion color. The limestone conglomerates, of which the lowest one is taken as the base of the formation, may be from 1 to 10 feet in thickness and are of a somewhat lighter color than the other beds. They are composed almost entirely of small limestone pebbles or fragments held in a calcareous earthy cement and are extremely persistent over wide areas, forming many notable escarpments. In the Ouray region the conglomerates are uniformly fine grained, the pebbles or fragments not exceeding 1 or 2 inches in diameter, and as a rule being still smaller. When the pebbles are very small and uniform the rock resembles pisolite. In places the limestone is in small, angular fragments and the rock may have somewhat the appearance of a recemented friction breccia or intraformational conglomerate. The limestone is dense and hard and of a buff or bluish color. The cementing material, as a rule less in amount than the pebbles, is dull red and calcareous, and contains considerable earthy impurity and locally a very little quartz sand.

From these conglomerates vertebrate and invertebrate fossils have been obtained, by means of which it has been possible to determine the Triassic age of the formation. No fossils of determinative value have been found in the Ouray quadrangle, although poorly preserved fragments of bone and teeth are abundant. Elsewhere teeth and bone fragments of a crocodile (*Belodon*) and of a megalosauroid dinosaur (*Palæoctonus*) have been found and are regarded by F. A. Lucas, who determined them, as of distinctly Triassic types.

Besides these vertebrates the Dolores beds have yielded a poorly preserved gasteropod, similar to *Viviparus*, and a *Unio*. One determinable plant, *Pachyphyllum münsteri*, has been found. For further details concerning the formation reference may be made to the Telluride folio, to the report on the Rico Mountains,[1] and to the paper already cited, on the "Red Beds."

Distribution.—The Dolores occurs in the Uncompahgre Valley, directly beneath the La Plata sandstone, extending from The Amphitheater on the east and the Canyon Creek laccolith on the west northward to the mouth of Coal Creek. Its unconformable relation to the Dolores and Hermosa is particularly well shown at the end of the ridge between Cascade Creek and The Amphitheater 1200 feet above the town of Ouray, as illustrated in fig. 7 (illustration sheet). North of Dexter and Corbett creeks the unconformity is no longer clearly evident and the formation, high up on the valley sides, can not be distinguished at a distance from the underlying Cutler beds.

In Cow Creek, although the Cutler is present, the Dolores does not occur, the La Plata, through the unconformity at its base, resting upon the Permian "Red Beds."

JURASSIC SYSTEM.

LA PLATA SANDSTONE.

Name and definition.—The La Plata sandstone was first described in the Telluride folio, its name being suggested by its widespread occurrence in the La Plata Mountains. It was defined to include a marked lithologic unit consisting principally of two massive sandstones with a variable calcareous member between them lying at the base of the fresh-water complex assigned to the Jurassic in Colorado. The thickness of the formation is at a maximum 500 feet in the La Plata Mountains, decreasing northward to 100 feet in the Telluride and Ouray areas. The sandstones are ordinarily milk-white, quartzose, and very massive; they vary somewhat in relative thickness and to the north and west have a deep yellow, orange, or red color. The calcareous member reaches a thickness of 30 feet in the La Platas, but in general is less than 15 feet thick. The base of the formation is the well-known plane of unconformity by which the lower sandstone overlaps all older sedimentary rocks to the Archean, as shown north of the San Juan Mountains and elsewhere. This angular unconformity is evident in Cow Creek, where the La Plata rests upon the Cutler red beds, the Dolores and probably not a little of the upper part of the Cutler being absent. The upper limit of the La Plata is placed at the base of a marked clay shale of green or reddish color which begins the alternating series of shales and sandstones grouped in the McElmo formation. No determinable fossils have been found in the La Plata formation adjacent to the San Juan Mountains.

Description.—In the Ouray quadrangle the La Plata sandstone does not as a rule exceed 100 feet in thickness and in some localities is even less. The lower sandstone member comprises fully three-fourths of the whole formation, ranging from 60 to 80 feet in thickness. The calcareous member varies from 8 to 15 feet, and the upper sandstone has an average thickness of about 10 feet. The lower sandstone has a cream or light-buff color, becoming grayish near the top. In one fairly characteristic section examined in the Uncompahgre Valley the rock was soft and friable and of a fine, even grain. Near the top it was impregnated with some soluble salt and where this had been removed the rock crumbled to a fine soft sand. In the region between Dexter Creek and Canyon Creek, however, both the lower and upper sandstones have been silicified and hardened, in many places to quartzites, by some processes probably related to the intrusions of monzonite porphyry. The occurrences in Cow Creek, where they are also quartzitic, are almost the only ones in which the cliff-making quality, so typical farther south, has been developed. The upper sandstone is essentially the same as the lower member, but thinner and apt to be more crumbling.

The local development of the calcareous member is probably the most striking feature of the La Plata in the Ouray quadrangle. Although varying somewhat from place to place, two portions can generally be recognized. The lower part consists of black laminated shale and limestone, few of the massive layers being more than 4 or 5 inches thick. Some folding or brecciation is noticeable in these beds, especially near the top. This part may be altogether absent and when present does not exceed 5 feet in thickness. Above it are from 8 to 10 feet of a breccia composed of small fragments of black limestone and shale, none exceeding 2 inches in length and most of them much smaller; they are sharply angular and seem identical in character with the limestone beds below. Although stratification is at many places visible throughout the bed the fragments are not everywhere arranged with their longer diameters parallel. This breccia almost invariably forms a ledge or cliff outcrop and it is very persistent throughout the Ouray region. It has been the means of identifying the presence of the La Plata where the sandstone members have been obscured.

Distribution.—The La Plata sandstone is exposed on both sides of the Uncompahgre Valley from the vicinity of Ouray to a point near the mouth of Coal Creek, where the northwesterly dip carries the beds below the level of the valley. To the south, on the east side of the river, the beds are cut off by the unconformity at the base of the San Juan tuff, but disappear beneath the landslide débris of The Amphitheater; on the west side they cross Oak Creek and continue up the northwest side of Canyon Creek to the point where they are cut off by the laccolith of monzonite porphyry. The La Plata also occurs in Cow Creek southward from the vicinity of Ramshorn Ridge to the mouth of Oban Creek. The beds are not present on the east side of Cow Creek south of Red Creek, having disappeared through the unconformity at the base of the Telluride.

M'ELMO FORMATION.

Name.—The McElmo formation was named in the Telluride folio from an important tributary of San Juan River heading on the Dolores Plateau. In the main McElmo Valley and in its side canyons the strata of the formation are well exposed below the Dakota. The formation does not appear to be divisible in this region or in other parts of the San Juan where it has been observed, as the individual beds are too thin to be mapped separately.

Description.—The McElmo formation consists of an alternating series of sandstones and shales, which varies considerably both in total thickness and in lithologic character. The sandstone beds are much like those of the La Plata and Dakota. They are fine grained, quartzose, friable, and gray in color; the lateral variation in thickness is marked, as also the transitions to shaly sandstones by increase of argillaceous matter. A characteristic of many sandstones is the abundance in them of green shale flakes or scales, a feature which is of value in distinguishing the McElmo from the Dakota or the La Plata where exposures are poor. Few of the sandstones exceed 20 feet in thickness.

The shales are of various colors. Greens predominate near the top, and, in fact, are found everywhere in the section, but from the middle of the section downward, reds and browns become very prominent; some bands are nearly pure white or cream colored. Many of the shales are extremely dense and fine grained in the Ouray district and have a distinct porcelain-like texture. As a rule, however, they are not free from sand, and a gradation to sandstone is more common than sharp lines of division.

The induration of the McElmo beds varies from place to place and also within the section at a given locality as illustrated in the accompanying section. In the areas of metalliferous deposits the sandstones are commonly changed to quartzite.

The average thickness of the McElmo in the Ouray quadrangle is 700 feet, the maximum being somewhat over 800 and the least observed about 500 feet.

The highest and lowest beds assigned to the McElmo are shales that are strongly marked and highly colored, contrasting with the Dakota and La Plata sandstones.

Section.—The best outcrops of the McElmo formation near Ouray are those on the east side of the river, above the Pony Express mine, south of Dexter Creek. At this point the following section extends downward from the base of the Dakota formation:

Section of McElmo formation south of Dexter Creek.

		Feet.
26.	Shales, slaty, black, alternating with shaly bituminous sandstone; individual layers less than 2 feet thick	16
25.	Sandstones, yellowish or greenish, with shaly layers	14
24.	Quartzite, dense, gray	6
23.	Shales, sandy, black; and fine-grained sandstones, largely quartzitic, thin bedded	23
22.	Quartzite, hard, white	20
21.	Sandstone, friable, white, containing clay	10
20.	Porcelain shales and thin argillaceous sandstones	21
19.	Shales, fine grained near top, dense, porcelain-like below, with sandy layers	42
18.	Quartzite, massive, white, more friable below, with thin clay layers near base	5
17.	Sandstone, coarse, white, lower portion indurated and containing a 2-foot shale layer	13
16.	Shale, green, with some purple and gray layers, very fine grained, much of it hard like porcelain; some sandy layers, more numerous near base; dark red; rests upon 5 feet of very white and massive porcelain shales	50
15.	Shale, red, sandy, and shaly sandstone	16
14.	Green and red porcelain shales and sandstones with a 2-foot pink, fine-grained limestone at the top	78
13.	Sandstone, massive, green above, white below	9
12.	Sandy shales and shaly sandstones, green, white, and red	69
11.	Sandstone, white, saccharoidal	20
10.	Sandstones and sandy shales, with some porcelain layers, red and green	26
9.	Sandstone, massive, fine grained, gray, white	10
8.	Sandy shale and sandstone, alternating green and red	20
7.	Sandstone, fine, greenish white, becoming red and shaly below	17
6.	Sandstone, extremely massive, white; red stains from shales above; quartzite in lower part and a thin green shaly layer near base	70
5.	Sandstones, with thin limestones and calcareous shaly layers; some reds and pinks, prevailing colors buffs and yellows	120
4.	Sandstones, heavy bedded, saccharoidal	11
3.	Shale and thinly bedded buff sandstone	10
2.	Quartzite, light colored, with bluish stains	18
1.	Sandstones and shales, red	65
	La Plata sandstone.	779

Distribution.—The McElmo has essentially the same distribution in the quadrangle as the La Plata, being present on both sides of the Uncompahgre Valley from Canyon Creek and The Amphitheater northwestward beyond the mouth of Coal Creek, and again in Cow Creek near Ramshorn Ridge. In addition to these localities its upper members

[1] Cross, W., and Spencer, A. C., Geology of Rico Mountains: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 67–73.

occur near Dallas and farther north, their reappearance being due to the east-west fault which crosses Uncompahgre River a mile south of Dallas. The formation, with the exception of the lowest beds, may be seen to best advantage in this last area. Notwithstanding its thickness and prominent position in the section of the Uncompahgre Valley farther south, it is, as a rule, poorly exposed, partly on account of its shaly character and partly because of the abundance of glacial drift that covers much of the valley sides.

Age and correlation.—The McElmo formation appears on stratigraphic and lithologic grounds to occupy the place of Lower Cretaceous sediments; but its age is assumed to be Jurassic, from the opinion prevalent among paleontologists concerning the vertebrate fauna long known from the Morrison formation on the eastern flanks of the Front Range and in the equivalent Como beds of Wyoming. *Morosaurus* and other representatives of this fauna have recently been found by E. S. Riggs in McElmo beds in the Grand River Valley at the north end of the Uncompahgre Plateau. The McElmo represents the upper part of the Gunnison group. That the McElmo, Morrison, and Como formations embrace certain equivalent strata is a conclusion scarcely open to further question. That the three formations are coextensive and thus fully equivalent cannot be considered as demonstrated by present knowledge.

CRETACEOUS SYSTEM.

DAKOTA SANDSTONE.

Description.—The lowest member of the Cretaceous, succeeding the McElmo formation with apparent conformity, is the Dakota sandstone. It is here, as commonly in Colorado, a series of extremely variable gray or brown quartzose sandstones, in many places cross-bedded, with several shale layers at different horizons. Its thickness in the Ouray quadrangle is in general 100 feet and nowhere exceeds 150 feet. The Dakota is commonly indurated to a greater extent than the La Plata sandstone, and the term quartzite is locally appropriate to designate it, especially in the vicinity of metalliferous deposits.

The basal conglomerate, carrying small chert pebbles of white, dark-gray, or reddish color, which is so persistent over large areas elsewhere in the Rocky Mountains, is here practically lacking, although a few pebbles occur at places in the lower beds.

The shale members are well developed near the middle and also near the top of the series. They are dark and strongly carbonaceous, with abundant indistinct plant remains, and north of Dallas and near the point where Cow Creek joins Uncompahgre River there is at one or both of the shale horizons a thin coal seam, sufficient to induce prospecting on its outcrops, but nowhere of much economic importance. As elsewhere in the San Juan Mountains the variability of the sandstones in thickness and in purity makes close correlations of sections from different places difficult. In the Ouray quadrangle the sandstones are all much indurated and almost everywhere occur as very hard massive quartzites, a facies that is not uncommon to the Dakota in other regions. It therefore resists erosion and becomes very prominent in the valley sides and in scarps facing the canyons that cut below it in the plateau country. It forms the floor of the Dolores and Uncompahgre plateaus over hundreds of square miles, thin remnants of the Mancos shale resting upon it and producing minor undulations. No determinable fossils have been discovered in the Dakota in this region, but indistinct plant remains and a few leaves occur in the shale layers.

Distribution.—Except in a few places where it is covered by landslide débris, the Dakota is almost continuously exposed on both sides of the Uncompahgre Valley from The Amphitheater and a point a little south of Oak Creek nearly to the great moraine which crosses the valley just above the junction with Dallas Creek. It forms a prominent ledge outcrop high up on the valley sides, and only at its northern limits does an increased northerly dip carry it down nearly to the level of the valley. The presence of the moraine obscures the actual disappearance of the formation due to the dip, but just west of the quadrangle, near the town of Ridgway, the descent of the beds is very clearly shown.

A little over a mile south of Dallas the Dakota reappears along a fault, which can be traced for many miles westward. A number of northeast-southwest faults of no great displacement cause breaks in the continuity of the Dakota east of the river and within a short distance an easterly dip carries the sandstones beneath the soft Mancos shales. West of the river an edge of a mesa, which is part of the great Uncompahgre Plateau, enters the quadrangle. Here the Dakota assumes its most characteristic physiographic expression as the capping formation, with a bold escarpment bounding the mesa on all sides. In this region and especially about the mouth of Cow Creek and on the west side of the mesa between that creek and Uncompahgre River thin coal seams have been locally prospected. The deposits are too thin and discontinuous and the coal is of too poor a quality to be of any commercial value. They occur near the top of the Dakota in a series of thin sandstones and bituminous shales beneath the uppermost massive sandstones or quartzites.

Cow Creek in the vicinity of Ramshorn Ridge is the only other locality in the quadrangle where the Dakota occurs. On the west side of the creek it dips steeply to the north beneath the monzonite-porphyry laccolith. It occurs again on the east side of the stream, but here it lies above the main porphyry intrusion, a considerable thickness of the McElmo shales intervening between it and the porphyry. Its southern extension is here limited by the unconformable Telluride conglomerate.

MANCOS SHALE.

Name.—The Mancos formation was first named in the Telluride folio from its characteristic development in the valley of Mancos River, an important tributary of San Juan River rising on the western slopes of the La Plata Mountains. It consists there of about 1200 feet of soft black or dark-gray carbonaceous shales, containing some very thin bands of impure fossiliferous limestone, which are too few and discontinuous to serve as practical guides in subdivisions of the great shale series in which they occur. The formation is sharply limited below by the massive sandstone of the Dakota and above by the lowest sandstone member of the Mesaverde formation of sandstones and shales. As was pointed out in the La Plata folio, the Mancos shale is a lithologic unit which embraces the Colorado group and a part of the Pierre division of the Montana group.

Description.—The Mancos shale is very similar to the most typical clay shales found commonly in the Colorado group elsewhere in the State. It is in few places as highly bituminous as the Benton shale along the foothills of the Front Range, but it has much less sand mixed with it than is commonly found in the Pierre shales of the Denver region. Where fresh the colors are dark leaden grays, in places with a greenish tinge; on weathering the shales become yellow or buff.

The calcareous and locally sandy layers containing fossils occur most abundantly near the base of the formation or else well up toward the top; yet some fossils are found nearer the middle of the section. The lower fossil-bearing beds have long been known. In the course of mapping the Telluride, Rico, La Plata, Durango, and Ouray quadrangles, and in reconnaissance work in adjoining areas, the various fossiliferous horizons have been seen and persistent faunas have been found.

At some localities in the San Juan region *Gryphæa newberryi* Stanton is abundant in the lower 100 or 150 feet of shales, and a somewhat higher zone is characterized by *Prionocyclus macombi* Meek, *Inoceramus dimidius* White, *Ostrea lugubris* Conrad, and other typical Benton species.

The Pierre species from the upper part of the Mancos shale include *Inoceramus crippsii* var. *barabini* Morton, *Syncyclonema rigida* (H. and M.), *Baculites compressus* Say?, and species of *Mactra*, *Scaphites*, etc.

In the Ouray quadrangle the Mancos shale is not protected above by any massive formations, and areas occupied by it have only moderate relief. None of the rocks are resistant enough to form cliffs or escarpments and the sides of such isolated hills or mesas as are formed of them, though at many points steep, are smooth and covered with the clay soil that results from the weathering of the shale.

Distribution.—The Mancos shale occupies nearly one-third of the area of the Ouray quadrangle, and except for a few isolated occurrences above the Dakota in the vicinity of Dexter, Cutler, and Coal creeks, it lies wholly to the northwest of the mountain front. The shales are, as a rule, poorly exposed, but their presence is easily recognized by the stiff clay soils, which have a characteristic yellowish-drab or gray color. The only region where even partial sections of the Mancos are well exposed is that lying between Dry Creek and Uncompahgre River, especially in the dry ravine between the two large moraines shown on the map. As has been already said, thin remnants of the Mancos occur at a number of places along the upper Uncompahgre Valley; they are covered either by the Telluride conglomerate or by the San Juan tuff, and have served, in not a few localities, as convenient horizons, for the intrusion of the monzonite porphyry of the region. Between Corbett Creek and Coal Creek there may be a considerable thickness of the shales, but they are obscured by Pleistocene and Recent landslides or glacial gravels.

MESAVERDE FORMATION.

Name and description.—The Mesaverde formation was characterized in the La Plata folio as a succession of alternating sandstones and shales, with a few marls or thin limestones, and a number of coal seams. The name was first applied by W. H. Holmes and was suggested by the very characteristic occurrence of the formation in the Mesa Verde, southwest of the San Juan Mountains. The formation has a maximum thickness in the Mesa Verde district of 1200 feet; it is lithologically distinct from the soft black shales of the Mancos formation upon which it rests, and from the heavy Lewis shale succeeding it.

In his original description Holmes recognized three divisions of the formation—the "Lower Escarpment sandstone," the "Middle Coal group," and the "Upper Escarpment sandstone." Considerable variation is found, however, in the development of the different members, in both thickness and hardness, and distinct scarps are not everywhere present. The "Middle Coal group," which in the Mesa Verde section occurs about 400 feet above the base of the formation, consists of about 600 feet of grayish shales and sandstones, with coal seams abundant throughout the section. It is in most places, owing to its soft, friable nature, poorly exposed, except in such semiarid regions as the Mesa Verde. Below the coal group are nearly 400 feet of alternating sandstones and shales with the massive "Lower Escarpment" sandstone at the top varying from 100 to 150 feet in thickness. Above the coal horizons is the "Upper Escarpment" sandstone, which may reach a thickness of 200 feet in the vicinity of San Juan River, but near the La Platas does not exceed 25 feet.

Distribution and occurrence.—The Mesaverde has a considerable areal distribution to the south and west of the San Juan Mountains and is very important economically on account of the excellent coal that has been found in it at a number of localities. The strata referred to the Mesaverde in the Ouray quadrangle are very much obscured by glacial and landslide débris, so that neither extent nor thickness can be accurately determined. At two localities on the headwaters of Lou Creek, a tributary of Cow Creek, coal seams have been opened and coal of an inferior quality has been taken out in small quantities. A mile or so north of the quadrangle, in the Deer Creek and Burro Creek drainages, more extensive prospecting has been done and one of the two seams is now being worked for local consumption. The deposits are from 12 to 20 feet thick, and, except at the Burro Creek openings, where heavy, crumbling, light-yellow sandstones occur above and below the lower coal seam, the rocks with which the coals are associated are nowhere exposed. This is due, in part, to the extremely soft, friable nature of the beds, but more especially to the heavy mantle of landslide débris and old glacial drift which completely covers the western slopes below Cimarron Ridge.

The position of the coal deposits with reference to the Mancos formation and the presence of the heavy sandstones observed in association with them north of the quadrangle are sufficient grounds for recognizing the Mesaverde formation, but from the lack of exposures little can be said of the local character of the formation. The boundary also between the Mancos and Mesaverde is purely hypothetical and has been drawn on the map with reference to the outcrops of coal seams, as shown by old workings.

Age.—From invertebrate fossils found at various horizons in the La Plata quadrangle and adjacent districts the Mesaverde has been referred by T. W. Stanton to the Pierre portion of the Montana group. There is no ground for assigning the formation to the Fox Hills, as was done by the Hayden Survey. Among the more important species recognized are the following:

Inoceramus crippsii var. barabini Morton.
Cardium bellulum Meek.
Cardium speciosum M. and H.
Callista deweyi M. and H.
Anchura newberryi Meek.
Actæon intercalaris Meek.
Baculites compressus Say.
Baculites anceps var. obtusus Meek.
Placenticeras intercalare M. and H.

TERTIARY SYSTEM.

EOCENE (?) SERIES.

TELLURIDE CONGLOMERATE.

Name and definition.—The Telluride conglomerate is a well-marked formation which underlies the San Juan tuff and was formed in the period immediately preceding the beginning of the long succession of volcanic eruptions in this region. It includes the sediments first deposited after the tremendous erosion that prepared the peneplain upon which it rests. It was first identified in the Telluride quadrangle, where it is well developed and revealed for examination, and was renamed after that area in the Silverton folio, as it was found that the term San Miguel, under which it was originally described, had been previously given to a Cretaceous formation in Texas.

Description.—The Telluride formation varies greatly in texture and thickness from a thin, coarse conglomerate in the Silverton and Ouray quadrangles to a complex of fine-grained conglomerates, sandstones, and shales about 1000 feet in thickness, as developed in Mount Wilson, on the western border of the Telluride area. It is made up of detritus of schists, granite, Algonkian quartzite and slate, and lesser amounts of the harder sediments of the Paleozoic formation—in particular of limestone.

In the Ouray area a granite porphyry that megascopically resembles a coarse andesite is abundantly represented in the pebbles and bowlders at almost all the localities where the Telluride has been studied; greenstones also are common.

On Cow Creek and in various places farther north an impure red limestone occurs within a few feet of the base of the formation. It is about 10 feet thick and grades upward into a coarse pink and brown grit which in many places becomes coarsely conglomeratic. Some of the bowlders of the conglomerate exceed 1 foot in diameter, but they are generally only a few inches. Many are well rounded, but subangular fragments are common, especially of the local material that has not been transported far.

Stratigraphic relations.—There is a great stratigraphic break below the Telluride conglomerate, as is evident from the character of its pebbles and bowlders, which were derived from many older formations. The magnitude of the break thus indicated is confirmed by angular unconformity, best exhibited on the southern side of the San Juan Mountains in the Silverton and Telluride quadrangles. In these areas the conglomerate visibly transgresses the edges of upturned and eroded sedimentary beds from the pre-Cambrian to a horizon well up in the Mancos shale. For a discussion of the peneplanation resulting in the surface upon which the conglomerate rests, and for other stratigraphic details, the reader is referred to the Silverton folio.

In the Ouray quadrangle the Telluride conglomerate is not continuous and hence the angular unconformity at its base is not so prominent as elsewhere; but the map shows that the conglomerate rests upon various formations from the Hermosa (Carboniferous) to the Mesaverde (Cretaceous), and small patches are known between the San Juan tuff and Algonkian beds in the Uncompahgre Canyon less than a mile south of the quadrangle line.

The Telluride conglomerate is in most places apparently conformable with the overlying San Juan tuff, but there was much erosion, locally at least, between the two epochs of deposition, as is best shown in the Silverton quadrangle. It is possible that the discontinuity of the conglomerate in the Ouray area is due to that erosion, although proof of such action has not been obtained.

Though volcanic material appears to be absent from the Telluride conglomerate proper, nonigneous pebbles occur locally in the San Juan tuff near its base and in a few places a transition zone of mixed conglomerate has been observed.

Distribution.—The Telluride conglomerate occurs at a number of widely separated localities in the Ouray quadrangle. A thin but characteristic band extends on the west side of Canyon Creek from a point near Oak Creek to the laccolith of monzonite porphyry that cuts across it and upward into the San Juan tuff. The unconformity at the base of the Telluride is well shown here, the conglomerate resting upon the Dakota near Oak Creek and upon the McElmo farther south. The only other occurrences west of the Uncompahgre are near the head of Coal Creek and just north of Corbett Creek. These two exposures are believed to be connected with one another, but the enormous accumulation of landslide débris on the broad ridge between Coal Creek and Uncompahgre River has completely covered the intervening space.

From the end of the ridge north of Cutler Creek continuous exposures of the Telluride, covered at first by the San Juan and later by the Potosi tuffs, may be traced around the western and northern flanks of Baldy Peak, past Cobbs Gulch to Cow Creek, on both sides of which it is exposed to a point a third of a mile south of Oban Creek. At its southernmost exposures, except in a few places where it is obscured by landslide débris, it rests upon the La Plata on the west side and upon the Cutler red beds on the east side. Northward the La Plata, McElmo, and Dakota successively appear, and north of Courthouse Creek the Telluride rests upon the Mancos shale. From Courthouse Creek northward exposures are rare and north of Nate Creek possible outcrops are covered by landslide débris as far as North Fork of Lou Creek, where the conglomerate rests upon the Mesaverde formation.

Age and correlation.—The Telluride conglomerate has as yet yielded no fossils by which its age may be determined. The reference to the Eocene in this place is in accord with the procedure in the Telluride folio, no additional data bearing on the question having been discovered. The conglomerate is later than the great orogenic movement which affected the entire older sedimentary section of this region, and also later than the enormous erosion which produced the peneplain upon which it rests.

The relations mentioned suggest a correlation of the Telluride conglomerate with the Arapahoe formation of the Denver region, and such a comparison implies the further correlation of the San Juan tuffs with the Denver beds, which are composed largely of andesitic débris. Both the Arapahoe and Denver formations are fossiliferous, and paleontological opinion seems to be that they should be considered Cretaceous, although separated from the Laramie proper by an interval of great orogenic disturbance and subsequent erosion. The Denver beds have, in fact, an equivalent, indicated by plant remains, in the "Animas beds" of the section well shown a short distance below Durango, but there is no conglomerate comparable with the Telluride in that section and the correspondence of the San Juan tuffs with the "Animas beds" is purely lithological, so far as known. Under these circumstances it is thought best to await further investigation in the San Juan region before making any positive correlations of the Telluride and San Juan formations. For a discussion of this question the reader is referred to the Telluride folio and to the monograph (Mon. U. S. Geol. Survey, vol. 27) on the geology of the Denver Basin.

QUATERNARY SYSTEM.

INTRODUCTION.

Surficial deposits of Pleistocene and Recent age characteristic of glaciated mountain regions are well developed in the Ouray quadrangle. They comprise the alluvial or flood-plain deposits of the larger valleys, with associated fans of detritus at the mouths of tributary streams, moraines, terraces of glacial gravels, and also accumulations, covering considerable areas, of disordered land waste which have come to their present positions as landslides from the heights above. In addition to these surface deposits there are in certain of the high amphitheaters or cirques great talus heaps and "rock streams" such as are characteristic of many parts of the San Juan Mountains.

In the Ouray quadrangle the first direct evidence has been found of more than one stage of glaciation in the mountains of southwestern Colorado. Records of the latest stage are abundant throughout the San Juan and from time to time indications of an earlier glaciation have been observed, but the evidence bearing directly on this point is extremely meager. In this place only the character and distribution of the deposits are described, their origin and age being discussed under the heading "Historical geology." A special description of the glacial phenomena of the San Juan Mountains has been published.[1]

EARLIER DEPOSITS OF GLACIAL ORIGIN.

Moraines of the earlier stage.—In the area bounded by Lou Creek, Cow Creek, Cimarron Ridge, and the northern border of the quadrangle much of the ground is covered more or less thickly by gravels and bowlders; near Cimarron Ridge the deposits almost completely cover the shales and sandstones of the Mancos and Mesaverde formations. The débris lies in disordered heaps, modified somewhat by erosion, but in many places retaining the form of kettle moraines. The material consists of bowlders and pebbles derived from the San Juan agglomerates of the ridge, and, in addition, crumbling blocks of the agglomerate itself from 10 to 30 feet in diameter. Near the ridge these deposits, which are not thick, are covered by débris of recent landslides from the cliffs of the ridge. Except where obscured by landslides the slopes westward from Cimarron Ridge are the evengraded ones of low angles characteristic of a mature topography, but they have been materially modified by a renewal of the activity of the streams that drain them, and gravels are preserved in their original positions only on the divides and ridges between the incised streams; south of Lou Creek similar materials were undoubtedly present but practically all have been removed. The gravels were evidently laid down before the surface was dissected and they are therefore believed to have been deposited by glacial or névé ice at a period or periods much earlier than the one during which the great moraines of the Uncompahgre Valley were formed.

Terrace gravels—earlier stage.—Gravel-covered terraces occur at two well-marked levels below that of the old drift. The upper terrace is merely an extension of the old graded surface upon which the drift rests, and is covered by stratified gravels separated by a rather indefinite line from the strictly morainal material. The terrace form and gravel cover are preserved only as remnants between the streams tributary to Cow Creek and in a few isolated hilltops and mesas, one of which, shown in fig. 10 of the sheet of illustrations, lies west of Cow Creek and nearly opposite Deer Creek.

The gravels consist entirely of material derived from the Potosi volcanic series and vary from an inch or less to a foot in diameter. The deposits are of variable thickness and are mostly thin near the old morainal material; the maximum observed thickness is 50 feet at the edges of terraces overlooking Cow Creek and on the mesa opposite Deer Creek—the only points where the gravels are well exposed, as they are elsewhere covered by 2 or 3 feet of fine reddish soil, possibly of eolian origin.

Earlier alluvium.—A second gravel-covered terrace occurs below the first one, the vertical distance between the two decreasing downward from the upper portions of the streams tributary to Cow Creek. At the mesa opposite Deer Creek their respective surfaces are a little over 200 feet apart, but on the sides of Deer Creek a difference of more than 400 feet exists. Intermediate terraces occur at a number of levels but they are poorly preserved and merge into one another, or into the main terraces, so that correlations are impossible. Remnants of this lower terrace are preserved as benches or isolated mesas on both sides of Cow Creek and Uncompahgre River and are the most striking topographic features of the northwestern part of the quadrangle. The terraces bordering directly on the Cow Creek drainage are covered by gravels composed almost entirely of volcanic material, the pebbles of the lower level being well rounded and waterworn. Both terraces are covered by a coating of fine red soil. These terraces are shown in fig. 10 of the illustration sheet; the inclined surface at the extreme right and the higher of the two small mesas seen in the middle distance belong to the upper level; the lower of the small mesas represents the lower terrace level.

The terrace gravels of the Uncompahgre drainage belonging to the lower level accord closely with those of Cow Creek in elevation, but the materials are somewhat different, comprising, in addition to volcanic rocks, porphyries, possibly derived from the Telluride conglomerate, and fragments of nearly all the sedimentary rocks of the Uncompahgre Valley, including Algonkian quartzites.

The origin and the age of these terraces and their gravel deposits are discussed in the section on historical geology, and the whole subject is treated in greater detail in the recently published paper on glacial phenomena which has been cited. It is sufficient to state at this point that all the deposits thus far described are older than the last stage of glaciation.

PLEISTOCENE LANDSLIDES.

In the Ouray quadrangle, as in other parts of the San Juan Mountains, landslides have taken place from time to time, and the great heaps of débris that have resulted from them are striking features of the topography, especially near Ouray. Elsewhere in the San Juan the landslides seem to have been of Recent age—that is, they occurred after the disappearance of the last glacial ice. The majority of the Ouray landslides undoubtedly belong to this time, since their detritus in many places rests upon moraine or drift.

The region lying between Coal Creek and Uncompahgre River, as well as more extensive areas west of the quadrangle, is unique in being covered with landslide débris of a much older period, believed to have been nearly contemporaneous with the earlier stage of glaciation. The accumulations cover the broad ridges between streams and rest upon what appears to have been a continuous surface extending northward with a very gentle slope from the foot of the mountains. There can be no doubt as to the landslide origin of the detritus, which consists of a chaotic mingling of San Juan and Potosi materials and blocks of Telluride conglomerate, angular and unstriated. The relatively great thickness of the masses near the foot of the mountains and their gradual thinning out at a distance from their sources are features characteristic of similar accumulations whose landslide origin is undoubted. The dissection of these deposits, as well as of the surface upon which they rest, corresponds in time and magnitude to the erosion that preceded the last stage of glaciation, as pointed out in the section on Pleistocene history. Their occurrence on both sides of Coal Creek near its mouth with exposures of the Dakota and McElmo beneath them proves conclusively that they could not have been laid down after the dissection of the upland.

The configuration of this landslide area is in itself an indication of its age, since its surface is rolling but no longer possesses the hummocked appearance characteristic of recently slidden material, and the enormous blocks of which it is composed, seen in exposures due to recent slips, have lost their angular outlines from long weathering.

LATER DEPOSITS OF GLACIAL ORIGIN.

Later moraines and drift.—Typical lateral and terminal moraines, whose forms have been modified but little since their deposition by the ice, occur in the three principal drainage systems of the quadrangle. The largest and most perfectly preserved are those of the Uncompahgre Valley. The great terminal moraine south of Dallas is over 400 feet high, and, including the portion lying west of the quadrangle, near the town of Ridgway, is more than 2 miles long, with an average width of 1 mile. It has relatively steep upstream faces and gentler slopes downstream with a very uneven, hummocked surface containing numerous small depressions or kettle holes, one of which, near the western boundary of the quadrangle, is large enough to be represented on the topographic map. The moraine is cut through about in the middle by Uncompahgre River, and exposures along the stream show the typical morainal character of the materials—unstratified subangular striated bowlders, gravel, and fine sand, representing all the rocks known to occur in the upper Uncompahgre Valley and its tributaries. The distance of this moraine from the head of Uncompahgre River and Canyon Creek is about 20 miles.

Another large moraine lies on the slopes north of Baldy Peak. The long ridge extending northwestward from the summit, although its form is not entirely due to morainal deposits, since it extends beyond them, is thickly covered with gravels and huge bowlders of San Juan tuff, massive Potosi agglomerate, Algonkian quartzites, some Dakota sandstone, and considerable monzonite porphyry. The greater part of this material was clearly derived from the Uncompahgre Glacier, but the numerous large bowlders of massive Potosi latite can have come only from the Cow Creek drainage, and it is believed that the drift covering the ridge, as well as that extending northeastward nearly to Cow Creek, represents a lateral moraine of the Uncompahgre Glacier, blending with the terminal moraines of the Cow Creek and Courthouse Creek glaciers. In addition to the more pronounced lateral moraines of the Uncompahgre Valley, most of which are on the western side, drift may be found on all the slopes that are not too steep, and at higher and higher elevations to the south, the highest observed being at 9500 feet on the north side of Bridalveil Creek, just south of the American Nettie mine. Notable accumulations of glacial gravels lie along Canyon Creek, just above its junction with the Uncompahgre, but the greater part has been removed by erosion and much is obscured by landslide débris.

In the Cimarron drainage basin areas greater than in other valleys are covered by drift, some of which, along Middle and West forks, has the characteristic form of lateral moraines; in general, however, most of the slopes are covered with a thick mantle of glacial débris without distinctive form, extending upward for nearly a thousand feet above the main stream. North of the point where West Fork joins the Cimarron, kames and kettle holes are common but no well-defined, continuous ridges of lateral moraines are preserved. In this region no indications of the earlier period recognized farther west have been found, although some of the higher drift under Cimarron Ridge and on the opposite side of the valley may belong to a stage earlier than that of the kettle moraine of the valley bottom. The low divide at the head of Owl Creek is covered with drift of the west Cimarron Glacier and the detritus may be traced for nearly a mile down Owl Creek, showing that at the time of maximum glaciation of the last stage a distributary of the west Cimarron ice stream crossed the divide and entered the Cow Creek drainage. This drift is distinct from that of the older period near the divide, but on its outer edges the two can not be clearly separated.

Later gravel-covered terraces.—Distinct terraces, gravel covered and similar in form to the older and higher ones previously described, occur on both sides of Uncompahgre River below the great moraine, and also on Cow Creek as far upstream as the mouth of Owl Creek. The level of these terraces is about 50 feet above that of the present flood plains of the streams. The gravels are waterworn, stratified, and of only moderate coarseness, few individual bowlders reaching 1 foot in diameter; their lithologic character is appropriate to the drainage in which they occur, those of Cow Creek being largely of Potosi materials, and those of the Uncompahgre consisting of sedimentary and volcanic rocks mingled.

The relation of the lower Uncompahgre terrace to the great moraine shows clearly that the gravels represent the outwash deposits laid down by waters escaping from the foot of the glacier and are essentially contemporaneous with the moraine itself. The gravels of the lowest Cow Creek terrace are

[1] Howe, E., and Cross, W., Bull. Geol. Soc. America, vol. 17, 1906, pp. 251-274.

of the same age and doubtless of similar origin, although their relation to a terminal moraine is not evident.

ALLUVIUM.

Alluvial sands and gravels, or flood-plain deposits, occupy all the larger valleys, the most notable being the broad and fertile flood plain of the Uncompahgre between Portland and the great moraine which, from its unusual width, causes the others of the region to seem almost insignificant. Similar though less extensive deposits of alluvium occur along the upper and lower reaches of the Uncompahgre, on Cow Creek, and on the two forks of the Cimarron that lie in this quadrangle.

Fan-shaped deposits of detritus occur at the mouths of many of the smaller streams; they consist of bowlders and gravels that have been carried down the gulches at times of unusual activity on the part of the streams and deposited on the flood plains or broad bottoms of the large valleys. Some of these alluvial fans, as that at the mouth of Portland Creek upon which the town of Ouray is built, may cover considerable areas. For the most part their outer portions are merged with the flood plains of the main streams and are not distinguished from them on the map.

RECENT LANDSLIDES.

In addition to the ancient landslides already described, others of more recent age have occurred at numerous places in the Ouray quadrangle. Their origin is discussed under the heading "Historical geology." Noteworthy slides are to be found in Coal Creek and on the east side of the ridge between that stream and Uncompahgre River, where slips have taken place involving in part the loosely consolidated materials of the Pleistocene slide deposits. Other slips have occurred about the head of Corbett Creek and on the north side of Cascade Mountain, where the accumulations are of sufficient thickness and extent to obscure completely the solid-rock geology over a considerable area.

The Amphitheater, directly east of Ouray, is filled to a depth of several hundred feet with landslide débris that fell from the cliffs of the San Juan formation in which the cirque has been eroded, and, although the deposits are covered for the most part with vegetation, Portland Creek and its side streams have carved deep trenches, in whose sides, which are at many places more than 200 feet high, the chaotic nature of the accumulations is well displayed.

No better example of the peculiar topography resulting from landslide débris coming to rest on moderately steep slopes can be found than that of the region southwest of Ouray lying between Canyon Creek and Uncompahgre River. The whole northwestern slope of the spur between these two streams is covered with great blocks of San Juan breccia, Telluride conglomerate, Hermosa sandstone, and fine detritus, which lie in disconnected but nearly parallel ridges with deep trenches between. Similar accumulations occur on Cow Creek near Red Creek and at the head of the main stream, on North Fork of Henson Creek, and on Middle and West forks of Cimarron Creek. Particularly extensive slides have taken place all along the western face of Cimarron Ridge, and the peculiar topography resulting from them can be recognized readily from a distance, although the surface is now covered with a thick mantle of vegetation.

In the extreme southeast corner of the quadrangle, south of North Fork of Henson Creek, is a large and instructive landslide area, extending eastward into the Lake City quadrangle. The ridge south of the stream, consisting of igneous rocks of the Silverton series, has been greatly shattered and nearly the whole slope for 2 or 3 miles is made up of landslide débris. Near the crest are some blocks several hundred feet in diameter, while on the lower slopes the detritus is much broken up and in part covered by vegetation.

ROCK STREAMS.

Certain peculiar masses of detritus known as rock streams occur in a number of high basins in the southeastern part of the quadrangle. They consist of large and small angular fragments of rock, derived mainly from the heads of the cirques in which they lie, and possess the sharp outline and in many places simulate the forms of small glaciers. The surfaces are as a rule ridged or furrowed, the lines strongly suggesting slow movement of the whole mass. The origin and character of the rock streams is discussed under the heading "Historical geology," and for further details the reader is referred to the Silverton folio, where these forms were first described.

IGNEOUS FORMATIONS.

SURFACE VOLCANIC ROCKS.

INTRODUCTORY STATEMENT.

The surface lavas and pyroclastics of the western San Juan have been referred to three principal divisions called the San Juan tuff and the Silverton and Potosi volcanic series. This grouping serves to bring out three great and clearly distinct epochs of eruption, and, further, to distinguish the lavas of these time divisions, which possess certain fairly well marked petrographic differences.

The San Juan tuff contains only fragmental material, the detritus of the earliest eruptions; the Silverton and Potosi series consist chiefly of lavas and contemporaneous tuffs. In general terms the San Juan consists mainly of andesitic lavas, the Silverton of latite and rhyolite alternating with andesite, and the Potosi chiefly of latite and rhyolite.

The full significance of the main eruptive epochs and of the intervals between them is perhaps best shown in the Silverton quadrangle, but the relations exhibited in the Ouray district throw light on some of the obscure points.

It is known that above the Potosi lavas later volcanic rocks occur, but the districts where these appear have not yet been studied in detail.

SAN JUAN TUFF.

Name and definition.—The earliest deposits of volcanic origin thus far observed in the San Juan Mountains consist of tuff, breccia, and agglomerate without intercalated lava flows. They represent the transported products of an earlier epoch, accumulated during a time in which no lavas were erupted, at least in the western San Juan. The simple term tuff will be used frequently in speaking of the whole formation, since fine-grained material is an important part of all the beds and is generally dominant.

The San Juan tuff overlies the Telluride conglomerate conformably through the greater part of the area in which the two have been found in contact, but that a time of important erosion intervened is shown in the Silverton quadrangle. Where the Telluride conglomerate is absent the San Juan tuff rests upon pre-Tertiary formations, in some places with pronounced unconformity. It is to be presumed that somewhere the San Juan overlaps the borders of earlier lavas representing a portion of the complex which has yielded the detritus for the clastic formation, but that relation has not been found and may be nowhere exposed.

The accumulation of the San Juan deposits was succeeded by great erosion before the earliest lavas of the Silverton epoch were poured out, and in many places the evidence of this erosion is seen in striking unconformities. The name San Juan has been used in several folios for this pyroclastic formation, which occurs normally between the Telluride conglomerate and the lowest lavas of the Silverton volcanic series. The formation has a maximum observed thickness of nearly 3000 feet in the walls of The Amphitheater, east of the town of Ouray.

Lithologic character.—Although composed almost exclusively of volcanic rock fragments, the San Juan presents much variety in aspect, due to differences in texture, the prominence or obscurity of its bedding, the variations in composition, and the degree of alteration it has undergone, affecting particularly its color. As the formation is a notable cliff maker, there are many opportunities for observing its general character, as well as for studying its composition in detail.

The San Juan has a distinct parallel bedding that is plain in all large exposures, but may be obscure within some of the coarser and more massive beds. The bedding is brought out by the alternation of layers of various textures and is much more pronounced in some places than in others.

The textural varieties range from fine sandy tuffs to coarse breccia, agglomerate, or conglomerate, but the intermediate phases in which angular, subangular, or, less commonly, well-rounded fragments are inclosed in a tuffaceous matrix, are most abundant. The term tuff-agglomerate best expresses its average mechanical character. By far the greater part of the formation consists of a tuff whose particles range from microscopic size to a few tenths of an inch in diameter, holding larger subangular fragments that reach a maximum diameter of 10 feet or more. The coarser beds are generally rather thick and the finer grained layers thin, and there is much variation in the relative amounts of fine- and coarse-grained beds in different parts of the section. There is, however, no regular progressive change from bottom to top of the formation. The coarse agglomerates are in many places extremely chaotic, and exhibit bedding only when viewed from a distance. Such deposits have a thickness of over 2000 feet near the forks of Cimarron Creek and, being poorly consolidated, weather in countless fantastic "hoodoo" forms, many rising as nearly vertical pinnacles or columns for over 200 feet, protected at the summit by a remnant of a more resistant layer or by a single large bowlder. Lenses of finer grained tuffs, many of them porcelain-like in texture, are found at numerous places in the midst of coarser material.

The fragments of the San Juan tuff are of andesite or latite, so far as known. But, though some of them contain much orthoclase in the groundmass, all are characterized by plagioclase phenocrysts, and microscopical or chemical examination is required to determine the latites. Labradorite is the common lime-soda feldspar occurring in phenocrysts. Since andesite is apparently much more abundant than latite, and the latite possesses the andesitic habit, it is sufficiently accurate for all general purposes to describe the materials of the San Juan as andesitic in petrographic character. None of the latites is of the facies to be described as prominent in the Silverton or Potosi series.

As to their dark silicate constituents the observed rocks range from pyroxene andesite to hornblende-biotite andesite or latite, with many intermediate varieties containing augite, hypersthene, hornblende, and biotite, one or more, in many degrees of relative and absolute abundance. The most basic rocks are the pyroxene andesites, the most siliceous are quartz-bearing hornblende-biotite latites.

In texture the rocks naturally exhibit much variety. Most of them are rather obscurely porphyritic, some are clearly of that texture, and others are dense aphanites. Nearly all the types possess the microscopic textures and other features of surface lavas rather than of intrusive rocks, but highly vesicular forms are extremely rare, and those with a glassy base are by no means common.

The San Juan tuff of the Ouray quadrangle exhibits a greater variety in the petrographic character of its component rocks than was observed in the Silverton or Telluride quadrangles, and this variety becomes still more striking in the Lake City area, lying to the east. This change in detailed constitution consists principally in the increasing abundance from west to east of very light colored hornblende-biotite or augite-biotite andesites and latites, of kinds not seen in the Telluride and Silverton districts. The significance of this observed fact will be referred to in discussing the origin of the formation.

A small amount of pre-Tertiary material, especially of granite and schist, was observed in the lower 200 feet of the San Juan tuff in the Telluride region, but this is not so noticeable in the Ouray quadrangle, except in the lower zone, a few feet or yards in thickness, where there is locally a mingling of volcanic materials with the materials of the Telluride conglomerate.

The general appearance of the San Juan pyroclastic beds is that most common for such materials. The less altered and less indurated parts are at many points colored pinkish, but many cliff exposures are dull green, reddish, or purplish in color, dependent largely on the kind and degree of alteration to which the tuffs and agglomerates have been subjected. The alteration is greatest in the southwestern part of the Ouray quadrangle, the soft greenish-gray or darker reddish tones of the cliffs in The Amphitheater or along Canyon Creek being very much like those in the adjacent Silverton and Telluride quadrangles. On branches of Cimarron Creek, however, the formation is less strongly colored, presenting the shades and tones more nearly normal for fresh aggregates of volcanic rocks. This general decomposition is thus greatest in the areas of extensive ore deposition, as might be naturally expected.

Origin.—The actual source or sources of the volcanic materials of the San Juan formation are unknown. The rock fragments do not seem to be of the nature of bombs or lapilli ejected in a partially molten condition from an explosive volcano. They appear rather to represent pre-San Juan lava flows or perhaps pyroclastic formations which have been broken up and their detritus transported from their original sites of consolidation or deposition. The great amount of volcanic débris and its multifarious constitution make it clear that a huge volcanic pile or several piles must have contributed to this San Juan detrital accumulation. Nothing yet observed locates clearly the situation of the older complex, but it seems almost certain that it must have been in the eastern or central San Juan Mountains, and that it was very largely destroyed in the process of forming the San Juan tuff and agglomerate. Its remains may be entirely hidden by the lavas and tuffs of the long succession of later Tertiary eruptions.

The San Juan formation does not represent, in the area thus far studied, a subaerial accumulation about an explosive vent, for its beds exhibit no tendency to dip away from a center. The detritus of the formation has, therefore, been transported, and fluviatile agencies appear to be the only ones capable of performing the gigantic work which has clearly been done. Certain portions of the San Juan tuff in the Telluride quadrangle may possibly be lake-bed deposits, as stated in the Telluride folio, but it is plain that most of the formation now known must have been a land or continental deposit.

Correlation and age.—The observed extension of the San Juan tuff northward along the narrow ridges between the branches of Cimarron Creek to a point within a few miles of Gunnison Canyon makes the conclusion unavoidable that the San Juan was once continuous with the "West Elk volcanic breccia," consisting of andesitic rocks, described in the Anthracite-Crested Butte folio. Although the Hayden map of the Gunnison Valley is incorrect in many important respects, it expresses well the broad fact, recently confirmed, that two volcanic formations of the West Elk and San Juan mountains formerly extended across the valley. These are the San Juan tuff and the Potosi volcanic series. Further investigation will be necessary to determine whether the San Juan and West Elk pyroclastic formations derived their materials from the same source or not, but it is at least true that they are contemporaneous deposits of the same general structural and lithologic character.

It was suggested in the Telluride and Silverton folios that the San Juan tuff might be in part equivalent to the "Animas beds" near Durango, which are known through their fossil flora to be equivalents of the Denver beds—that is to say, post-Laramie. In view of the magnitude and complexity of the San Juan tuff it is now considered more probable that the "Animas beds" belong to one of the pre-San Juan epochs of eruption.

No new evidence as to the age of the San Juan has been obtained in the Ouray quadrangle. It is manifestly much older than the calcareous tuffs of the Silverton series, which scanty plant and invertebrate fossils indicate to be of Oligocene or early Miocene age. As has been already stated, the formation must be younger than the enormous complex of lava flows whose destruction resulted in its accumulation, and nowhere in Colorado is there evidence of volcanic eruptions in the Cretaceous period until after the close of the Laramie proper. It is therefore plausible to refer the deposition of the San Juan formation to the Eocene.

Distribution.—The San Juan tuff occupies a large part of the quadrangle, as a glance at the geological map will show. Its exposures along the southern border are continuous with those of large areas in the Silverton and Telluride quadrangles. On the east it is prominent in several valleys and ridges of the Lake City quadrangle, but disappears gradually through the descent of the Potosi lavas.

Northward the San Juan and Potosi both extend within a few miles of the Gunnison Canyon, following the ridges between several streams, and the very similar clastic beds of the West Elk Mountains, called the "West Elk breccia," seem to have been once continuous with the San Juan, whether derived from the same immediate source or not.

SILVERTON VOLCANIC SERIES.

Name, Scope, and General Character.

The San Juan tuff was succeeded in the western San Juan region by a complex of lavas, tuffs, and agglomerates, named after the Silverton quadrangle, in which they have their greatest development. Between the deposition of the San Juan formation and the outpouring of these lavas there was extensive erosion of the former. For the reasons that the Silverton lavas appear to have been in large degree erupted within an erosional valley or basin, and that their outlying portions were eroded away before the next epoch of eruption, the rocks of this series now occupy comparatively small areas. They are the most important element among the rocks of the Silverton quadrangle, reaching an observed maximum thickness of about 3000 feet. To the west they thin out and within the Telluride quadrangle they disappear. In the Telluride folio they were called the "Intermediate series."

The Silverton rocks do not now extend south of the Telluride quadrangle. Eastward their development is subordinate and in the Ouray quadrangle, on the north, they occupy but a small area, as shown by the map, yet the relations of the Silverton tuffs and lavas exhibited in this district are of much importance to an understanding of the history of the series.

In the Silverton folio the Silverton volcanic series was divided into the following members, which were distinguished on the geological map of that folio:

1. Picayune andesite, the earliest lava of the series, of very local development, and not exposed in the Ouray quadrangle.

2. Eureka rhyolite, a flow breccia with subordinate tuffs. This rock occurs in heavy flows and was one of the most widely distributed of the Silverton lavas. It does not outcrop within the Ouray quadrangle, but extends down Henson Creek as far as Lake City, appearing within a mile of the southeast corner of this quadrangle.

3. Burns latite, a group of highly siliceous hornblendic lavas and tuffs consisting of several rocks of local importance, with two notable thin-bedded tuffs which serve as horizon markers. The upper tuff is the only portion of the Burns latite exposed in the Ouray quadrangle. It is particularly important because of fossil remains which, though scanty, give the only known direct evidence as to the age of any of the volcanic rocks of the San Juan region. The Burns latite was named from Burns Gulch, in the Silverton quadrangle. The rocks embraced under this head are principally massive flows of latite, a rock intermediate between trachyte and andesite. These latites are as a group characterized by hornblende. There are many different flows in the Silverton quadrangle, which overlap on their borders. The massive rocks are in some places separated by tuffs, but the principal development of such beds is at the base and at the top of the group.

4. Pyroxene andesite, the latest known massive lava of the Silverton epoch. This member is well developed in the Ouray quadrangle.

A fifth, uppermost member of the Silverton series, the Henson tuff, is distinguished in this folio for the first time. It rests upon the pyroxene andesite and through its structural relations becomes of much value as a cartographic unit.

The reader is referred to the Silverton folio for details concerning the earlier members of the Silverton series; those occurring in the Ouray quadrangle will now be described more fully.

Burns Tuff.

Occurrence and description.—The upper tuffs of the Burns latite occur in the bed of North Fork of Henson Creek near the eastern line of the Ouray quadrangle. They have been exposed through the deep erosion of this stream, which has cut through the pyroxene-andesite flows, and the underlying tuffs would now be seen in a narrow strip following the creek across the border into the Lake City quadrangle were it not for the obscuring landslide débris from the southern slope.

On the south side of North Fork of Henson Creek, 1 mile above the southern line of the quadrangle, the Burns tuff is well exposed to a thickness of about 75 feet. They are here well-stratified greenish-gray sandstones in which few grains exceed 3 mm. in diameter. The particles are much decomposed, representing latitic or andesitic lavas, mainly. Many layers are crumbling shales. A calcareous cement is more or less abundant, and thin gray or black limestone layers, from mere films to a few inches in thickness, are present at several horizons. Many of the thin shaly layers contain carbonaceous matter, chiefly as broken stems of undeterminable character. A few remains have been specifically identified, as is fully set forth in the next section.

These tuffs dip northeastward at about 10°. This structure, in which the overlying andesite flows participate, is required to bring the Burns tuff to the much higher levels which it occupies in the Silverton quadrangle, 3 or 4 miles to the south.

The Burns tuff reappears on the south side of the creek just west of the eastern border of the quadrangle, where it has been penetrated by the Deadwood tunnel. It is also well shown in a northern tributary of North Fork of Henson Creek less than half a mile within the Lake City quadrangle, where it contains a few fossil leaves. The southward rise of the tuffs may be traced from the Deadwood tunnel around the east end of the ridge between North Fork and the main Henson Creek, although landslide débris conceals them in many places.

Deposition and age.—The character of the upper Burns tuffs shows them to be waterlaid deposits, probably in lakes. The fossil plants from the calcareous shales of North Fork of Henson Creek have been determined by F. H. Knowlton as *Cratægus holmesii?* Lesq. and a new species of *Pinus*. The former occurs also at several places in the Silverton quadrangle. The type was found in a local rhyolitic tuff of the Rosita Hills, near Silver Cliff, Colo. In the Burns tuff of the Silverton quadrangle are several species of *Pinus*, in cones or leaves, and one of them is regarded by Knowlton as *Pinus florissanti?* Lesq., the type of which was found in the Oligocene lake beds at Florissant, Colo.

A limestone layer in the tuff near the Deadwood tunnel was observed by Benjamin Guionneau to be full of minute shells, which are said by R. S. Bassler to belong to the genera *Cypris* and *Bairdia*, of the Ostracoda. In the Silverton quadrangle some gasteropod shells occurring with the plants referred to are stated by T. W. Stanton to belong to two species of *Limnæa* very closely resembling *L. meekii* Evans and Shumard and *L. shumardi* Meek, which occur in the White River beds, usually assigned to the Miocene but considered by some paleontologists as Oligocene. According to the concurrent evidence of plants and shells the upper Burns tuffs may be regarded as Oligocene or early Miocene in age.

Pyroxene Andesite.

The Burns latite was succeeded by a series of flows of pyroxene andesite or latite with intercalated tuffs. These rocks reach their greatest development in the central part of the Silverton quadrangle, where they exceed 3000 feet in thickness.

Description.—The pyroxene andesites are dark, variably porphyritic lavas of dense texture in the greater part of each flow but vesicular in upper and lower zones. As developed in the Ouray quadrangle the vesicles are commonly filled by chalcedony, opal, quartz, and calcite. Scoriaceous zones occur between many flows. The individual flows vary in thickness, but few of them exceed 25 feet in the Ouray quadrangle.

Petrographically these rocks may be described as containing phenocrysts of labradorite, augite, and hypersthene in a groundmass rich in labradorite, orthoclase, and magnetite. Some of the flows in the Silverton quadrangle are so rich in orthoclase as to belong to the latite group, but the rocks of the Ouray district are more distinctly andesites. Hypersthene is commonly decomposed, yielding chlorite and serpentine. A brown glassy base is present in the contact zones of most flows. For a full description of the petrographic character of these rocks the reader is referred to the Silverton folio.

In the field the pyroxene-andesite exposures are characterized by the reddish-brown color of the massive rock, or by the nodules of agate, chalcedony, and other siliceous deposits in the vesicular zone, many of which have weathered out and are strewn over the surface.

Distribution.—The pyroxene andesites of the Silverton series appear only in the southeastern portions of the Ouray quadrangle. The principal exposures are in the southeast corner of the area at the head of North Fork of Henson Creek. They rise from the bed of the stream for more than 2000 feet to the crest of the ridge on the Silverton quadrangle line, possessing in general the northerly dip recorded for the underlying Burns tuffs. In the other occurrences of this vicinity they appear beneath the Henson tuffs through their erosion at the heads of Cow, Wildhorse, and Bear creeks, and are limited on the north by abutting against San Juan tuff.

In the southwest corner of the quadrangle the pyroxene andesite appears in Whitehouse Mountain as a nearly aphanitic flow 60 feet in thickness resting on San Juan tuff and overlain by tuff of the Potosi series. In Potosi Peak, about $1\frac{1}{2}$ miles to the south, the Silverton series is represented by 300 or 400 feet of flows and tuffs, and southward from that point the section rapidly thickens.

Henson Tuff.

Name, definition, and distribution.—It is here proposed to apply the name Henson tuff to a pyroclastic formation consisting chiefly of well-bedded, fine-grained, greenish or brownish-gray, sandy tuffs, composed of andesitic material and forming the uppermost division of the Silverton series. They lie upon the pyroxene andesites and are succeeded by the Potosi volcanic series. Their varied thicknesses and present restricted occurrence point to erosion of importance in the period immediately preceding the effusion of the lowest Potosi lavas of this district.

The name is derived from Henson Creek, on the headwaters of which the tuffs have their best known development. They are especially well exposed and reach their maximum observed thickness of 600 feet on the divide between North Fork of Henson Creek and Cow Creek in the Ouray quadrangle. They extend southward across American Flat and as far south as Engineer Mountain in the Silverton quadrangle, where they were seen during the survey of that area. But the relations of the tuffs were not understood at the time the Silverton folio was published, mainly because the body of quartz-mica latite shown on the Ouray map as an intrusive in the Henson tuff was regarded as the lowest flow of the Potosi series. The tuffs below that flow were therefore classed with the pyroxene andesite and those above it with the Potosi. The intrusive character of the quartz-mica latite is placed beyond question by occurrences within the Lake City quadrangle.

The cartographic distinction of the Henson tuff is warranted by its lithologic character and its representation assists materially in expressing the importance of the long Silverton epoch, between the San Juan and Potosi, of which there is no suggestion in the volcanic rocks of a large part of the Ouray and adjacent quadrangles.

Description.—The Henson tuff is very much like the Burns tuff in texture and composition and hence also in appearance. There are, however, no calcareous shales or limestone layers in the Henson tuff at the points where that formation has been examined. Much of the tuff consists of rather rounded sand grains, evidently derived in large degree from pyroxene andesite. Some grains exhibit parts of crystals of labradorite, augite, or hypersthene embedded in dark ferritic or microlitic groundmass, but many grains are without large crystals and probably represent particles of the andesitic groundmass. The tuff grains are in general only 2 or 3 mm. in diameter, and some beds consist of very fine particles. Bedding is nearly perfect, but is not conspicuous in some exposures owing to the uniform texture and friable condition of the strata.

The colors of the tuffs are either brownish or greenish as a rule, generally of dull hues, but in some places a vivid green, due to abundant chlorite, is strongly developed. The color of some such beds is visible for miles.

The Henson tuff at some localities carries angular or subangular fragments of pyroxene andesite, rhyolite, or quartz latite. The andesite is similar to the rock of the underlying flows, and the rhyolite and latite are distinctly of the facies of flows of the Potosi series and unlike any known earlier lavas. Such fragments reach a diameter of 1 foot or more and they have been found locally of such abundance as to make a volcanic breccia with subordinate tuff matrix. This phase of the Henson is well exposed on the divide between North Fork of Henson Creek and Cow Creek, on and near the trail. The tuffs on the south slope of Wildhorse Peak also contain many fragments of the rocks named. The occurrence of such rocks in the tuff of the latter locality was observed during the survey of the Silverton quadrangle and was one of the facts which led to a reference of these tuffs to the Potosi series.

No plant or other fossil remains have been found in the Henson tuff, in spite of its resemblance to the Burns tuff.

Relations.—The Henson tuff rests upon pyroxene andesite wherever the base is exposed in the Ouray quadrangle. A few miles farther east, in the Lake City area, the thinning out of the andesite flows causes the Henson and Burns tuffs to come in contact.

That pyroxene andesite and Henson tuff abut on the north against a San Juan surface of general southerly dip is amply shown by the limitation of the formations expressed by the map. Owing to landslide débris and intrusive bodies the actual contact with the San Juan is not well exposed in most localities; but on the west side of Wildhorse Creek and on the northern branch of North Fork of Henson Creek the relations are very clear.

The appearance of Potosi types of rhyolite and latite as fragments in the Henson tuff must indicate that the effusion of Potosi lavas had begun in some adjacent district before the accumulation of the Henson tuffs had ceased in the area now drained by Henson Creek. In all probability, therefore, the Henson tuff is really the last formation of the Silverton series, although the restricted occurrence and varying thickness of the tuffs suggest an erosion interval before the earliest Potosi lavas of the western San Juan Mountains, during which rocks not now represented at any locality may have been removed.

POTOSI VOLCANIC SERIES.

Name.—The uppermost division of the great volcanic complex developed in the western San Juan Mountains was described in the Silverton folio under the name "Potosi volcanic series." The same rocks had previously been called the "Potosi rhyolite series" in the Telluride folio, the change in name following a study of the more extensive complex in the Silverton quadrangle. In the original description of the series, as developed at the type locality of Potosi Peak, the rocks, consisting of massive flows with a few thin agglomerate and tuff beds, were referred to as rhyolites, although it was pointed out that the single available analysis showed a certain glassy facies to belong to the highly siliceous lavas, containing alkali and lime-soda feldspars (plagioclase) in nearly equal amount, that are properly designated as quartz latite. Analyses of rocks from a number of different localities in the Silverton quadrangle showed that the greater number were latites or quartz latites and that true rhyolites there form probably a subordinate part of the complex. To state the petrographic character of the series both rocks must be named.

Occurrence and distribution.—The rocks of the Potosi series, which once doubtless covered the entire area of the Ouray quadrangle, are now found only in high mountains of the southwestern and southeastern portions. Elsewhere erosion has removed them and exposed the older formations.

The remnant of the Potosi lavas in the southwest corner of the quadrangle composes the upper 1000 feet of Whitehouse Mountain and extends from that point along the sharp ridge connecting it with Potosi Peak, which lies just across the boundary in the Silverton quadrangle. In the southeastern portion of the quadrangle there are several isolated areas of Potosi rocks, as shown by the map. These exposures are but a few miles west of the large area of Potosi lavas occurring in the Lake City quadrangle, the thickest section being that of Uncompahgre Peak. Similar small areas of these lavas occur in the adjacent portion of the Silverton quadrangle.

The Potosi rocks of the southeastern part of the Ouray quadrangle represent the lower flows of the series, with some fragmental beds. They have been intruded by magmas which also belong in all probability to the Potosi series, and, as many of such intrusions have the texture of lava flows, with glassy or vesicular contact zones, some of them were not recognized during the Ouray field work as intrusions. They were not distinguished on the map unless their crosscutting relations were plain. It is now known that lavas of indistinguishable character occur in the upper part of the Potosi section of Uncompahgre Peak and that numerous dikes, sheets, and more irregular intrusions of the same magmas occur in the upper San Juan formation in the adjacent portion of the Lake City quadrangle.

The principal area where intrusive masses have been mapped with the Potosi flows is about Coxcomb Peak and in the high ridges southwest of Wetterhorn Peak. The massive rock which forms the upper 800 feet of the Wetterhorn and the sharp ridge north from it, and which also extends northeastward to the Matterhorn, a short distance within the Lake City quadrangle, is perhaps an intrusive, but the occurrence in the Matterhorn of much breccia composed mainly of the same type throws some doubt on such a conclusion. This type is not known elsewhere, a fact supporting the idea of its intrusive character.

Description.—The lowest portion of the Potosi in the Whitehouse Mountain area consists of about 50 feet of alternating thin flows and beds of coarse gravel-like tuff. The flows are characterized by marked fluidal texture on weathered surfaces and in thin sections. They contain many included fragments of the same kind of rock, in some places in sufficient abundance to become flow breccias. The rock is commonly pinkish in color, containing prominent phenocrysts of feldspar and a bronze mica in a felsitic or glassy groundmass. The feldspars are found to be andesine and orthoclase in nearly equal amounts. A little quartz is also present, both in phenocrysts and more abundantly in association with orthoclase in the groundmass wherever that is crystalline. The tuffs are poorly consolidated and consist of more or less rounded fragments, 1 to 6 inches in diameter, of latite and some andesite, held in a finer matrix of the same materials. Individual layers range from 1 to 5 feet in thickness.

Above these tuffs and thin flows are a few very massive flows of quartz latite, having a total thickness of about 500 feet. The rock is pink or purple and has abundant phenocrysts of both orthoclase and plagioclase. Nearly black or dark-bronze biotite, although not as abundant as either of the feldspars, is very conspicuous megascopically on account of its dark color and brilliant luster. Above the massive flows are 400 feet of thinner flows, with tuff layers here and there and at least two thin bands of dark glassy latite near the base.

Quartz latite occurs in the upper and lower parts of the section, but the massive flows near the middle are less siliceous. A lava from the summit of Whitehouse Mountain is one of the most distinct rhyolites of the series, as it contains only a very little plagioclase, but is rich in orthoclase and quartz with a little biotite. In many cases the groundmass is full of dark trichites which mark the fluidal texture. Spherulitic crystallization is not uncommon.

The lavas of the southeastern section, belonging undoubtedly to the Potosi series, are rather fine-grained pink or gray quartz latites with a variable development of biotite, hornblende, augite, and hypersthene, the biotite being most common. The dark constituents are everywhere subordinate. The feldspar phenocrysts, among which plagioclase is far more abundant than orthoclase, are as a rule greatly broken. Quartz is not uniformly developed in large crystals. The groundmass is in the main cryptocrystalline or partly glassy, with obscure spherulitic growth as a common feature. Much of it is clouded by ferritic specks and trichites, and generally it exhibits fluidal texture. From the analyses of a few Potosi rocks and the composition determinable in the more coarsely crystalline specimens, it is plain that quartz and orthoclase are everywhere the principal constituents of the groundmass.

Although quartz latite, rich in andesine or labradorite, is more common than true rhyolite, banded felsitic masses of the latter rock, almost free from plagioclase, occur sparingly. In Coxcomb Peak some of the rhyolite is notably spherulitic, nodules of this character several inches in diameter having been found.

The rock of the Wetterhorn, which may be an intrusive, as already noted, is a dark-gray porphyry with many phenocrysts of feldspar and biotite, few of which exceed 3 or 4 mm. in diameter. The groundmass is about equal to the phenocrysts in amount. Quartz and augite occur in phenocrysts, but are not prominent. A mottled appearance is given to the rock by the presence of many small aphanitic inclusions, most of them less than 1 inch in diameter. These inclusions appear to have the same mineral composition as the surrounding rock, but are much finer grained. The analysis of the Wetterhorn rock presented in the table of analyses (p. 12) shows it to be chemically near other rocks of the region, some of which are intrusive, while others are Potosi lavas.

The quartz latite of Wetterhorn Peak has a black vitrophyric lower contact zone on the ridge southeast of the peak. Such glassy zones are common in the intrusive masses of quartz latite and are also exhibited in certain masses supposed to be intrusive, but mapped as Potosi. One of the best localities to study this development is on the spur leading eastward from the summit with an elevation of 12,980 feet, just north of the trail divide between North Fork of Henson Creek and Cow Creek, at the level represented as the base of the Potosi series.

INTRUSIVE ROCKS.

INTRODUCTORY STATEMENT.

Within the Ouray quadrangle occur a great many dikes, sills, laccoliths, and irregular bodies of igneous rocks, appearing at all horizons from that of the oldest sedimentary beds to that of the youngest surface volcanics now remaining. These rocks belong to a number of petrographic types, nearly all of which correspond in chemical and mineral composition to certain of the effusive rocks, or lavas. As nearly all the intrusives are known to penetrate the lavas at some point, it is concluded that in general they represent the same magmas as the surface rocks, and that in many places the effusive and intrusive materials of the same composition are contemporaneous in origin.

In support of this conclusion, it is observable that the higher the horizon of intrusion the more do the textures of the intrusive rocks become like those of the corresponding effusive varieties. This similarity becomes so striking in the rocks of the higher horizons that certain of the intrusive masses were considered to be lava flows in the field work of the first season, because crosscutting relations were not clearly defined. Not all mistakes of this kind have been corrected. These textural differences among otherwise identical rocks lead to regrettable inconsistencies in nomenclature which can not well be avoided under the prevailing system of naming igneous rocks. Thus, the intrusive porphyries of lower horizons commonly have the microgranular groundmass texture characteristic of most deep-seated laccolithic rocks, and are described as monzonite porphyry, whereas rocks of the same magmas, at higher levels and with glassy contact zones and microlitic, perhaps fluidal, groundmasses, are termed latite, corresponding to the surface lavas they so closely resemble.

The principal groups of intrusive rocks will be described under the headings used on the geological map.

QUARTZ MONZONITE PORPHYRY.

Occurrence and distribution.—The rocks called quartz monzonite porphyry occur for the most part either in the sedimentary formations below the volcanic rocks or at the base of the volcanics. A few are dikes of higher levels in the San Juan formation. Nearly all the numerous dikes and sheets near Ouray and the larger bodies of Canyon Creek, Dexter Creek, and "the blowout," together with the laccolithic body of Cow Creek near Ramshorn Ridge, consist of quartz monzonite porphyry. Remarkably little variation in the composition of the rocks from different localities has been noted and only slight textural differences exist between the rock of dikes and that of larger bodies. In none of the occurrences has strictly fresh rock been found and no chemical analysis has been made, but the complete crystallinity of the rocks and their relatively simple texture have made satisfactory microscopical determination possible in a majority of cases.

One of the principal bodies of quartz monzonite porphyry is in Dexter Creek, where a large crosscutting mass rises from the stream for more than 1000 feet. It has been intruded partly in the Mancos shale and partly in the San Juan formation. A thick sheet extends to the west and south as an offshoot from the main mass; it lies between the Dakota and the base of the San Juan and seems to have followed the horizon of the very thin remnants of Mancos shale which were preserved on the Dakota surface at the time of the San Juan accumulation, for patches of the black shales are seen at many places above or below the porphyry or included in it. This body with its sheetlike apophysis is typical of the others of this area.

West of the Uncompahgre, between Oak and Corbett creeks, is a still larger body; its boundaries are not well exposed on account of the landslide débris which partially covers it, but its form seems to be nearly that of a laccolith intruded in the soft Mancos shales near the base of the San Juan. Local crosscutting conditions exist, especially with respect to the San Juan in Oak Creek. The porphyry body of Corbett Gulch and other isolated patches shown by the map are undoubtedly connected with this mass.

The laccolithic body of Canyon Creek, which extends into the Silverton quadrangle, has, likewise, been intruded at the base of the San Juan, but among strata of lower horizons than were the others so far described, lying for the most part below the La Plata sandstone. The base rests upon the Hermosa at the point where the body crosses the quadrangle boundary, but rises farther north to a horizon a little above the base of the Cutler formation; the upper contact is a crosscutting one and passes from the La Plata to and into the San Juan. Two sheets extend northward from the Canyon Creek body and after crossing Oak Creek become parts of the complicated system of sheets and dikes that are exposed in the cliffs northwest of Ouray, which can not be represented in detail on the present map.

The body of porphyry in the gulch between Bridalveil and Cascade creeks known locally as "the blowout" is so altered, as are also the sedimentary rocks near by, that the exact character of the intrusion is somewhat uncertain. The main mass appears to be crosscutting, and, though a majority of its many apophyses are dikes, a few penetrate the adjoining sedimentary rocks as sheets.

The porphyry bodies exposed on both sides of Cow Creek in the vicinity of Ramshorn Ridge are, like the others to the southwest, laccolithic, but extremely irregular and with many crosscutting relations. The intrusions occurred at a place where all the pre-Telluride formations are sharply folded in a monocline that gives the strata a steep northerly dip and causes the Dakota and older beds to disappear beneath the Mancos shale. West of Cow Creek the porphyry rests upon the inclined surface of the Dakota and seems to have invaded a wedge-shaped mass of Mancos shale which lay between the Dakota and the Telluride conglomerate. In the process the shales, which are highly contorted and indurated near the contacts, appear to have been forced aside and the Telluride elevated nearly 400 feet. At about the point where Cow Creek now flows the porphyry cut across the Dakota and east of the stream lies in the McElmo formation.

A second body, smaller than the first, is exposed a short distance to the north. It has been intruded entirely in the Mancos shale and its contacts are nearly parallel to those of the larger body. Although the two have not been observed to join, the smaller body is undoubtedly connected with the larger mass at a short distance below the surface and serves to emphasize the very irregular form of the intrusion as a whole.

A crosscutting body of quartz monzonite porphyry occurs on the eastern border of the quadrangle in Porphyry Basin, a tributary of Middle Fork of Cimarron Creek. The greater part of this body lies farther east in the Lake City quadrangle.

On the high divide between Cow Creek and the North Fork of Bear Creek occur several dikes or small irregular masses of a facies of quartz monzonite porphyry characterized by rather large phenocrysts. These bodies are undoubtedly of the same rock which forms a mountain summit between the forks of Bear Creek a short distance within the Silverton quadrangle.

Description.—The typical quartz monzonite porphyry is a moderately coarse grained rock, light gray in color, with a greenish tinge due to the presence of secondary chlorite. Phenocrysts of feldspar are very abundant and altered ferromagnesian minerals, hornblende and biotite, are generally present but subordinate in amount. The occurrence of quartz is somewhat variable; it may be present in megascopically visible grains, although as a rule the microscope is necessary for its determination. The groundmass of the rock is invariably holocrystalline and consists of a microgranular aggregate of orthoclase and quartz with a very little plagioclase and minute flakes of biotite. The feldspar phenocrysts consist of a soda-lime plagioclase, too much altered in most of the rock to permit an exact determination, but probably oligoclase or andesine. Orthoclase may also occur as phenocrysts, but is less abundant than plagioclase. Quartz appears in irregular corroded grains and is locally very abundant, especially in the "blowout" mass.

In the majority of the rocks secondary minerals now far exceed the original constituents. The alteration of the feldspars has resulted in the development of kaolin, sericite or muscovite, and calcite. Chlorite, calcite, and rarely epidote have followed the decomposition of hornblende or biotite. These changes are so widespread and so uniform in character that they can not be attributed solely to surface weathering, and it is believed that they are due to the action of mineralizing agents that closely followed the period of intrusion and were associated with the formation of many of the ore deposits of the region. These matters are discussed in greater detail in the section headed "Economic geology."

The rock of the quartz monzonite porphyry dikes in Porphyry Basin and on each side of Middle Fork of Cimarron Creek is slightly different from that of the laccolithic bodies and sheets near Ouray, being richer in hornblende and containing, as a rule, very little quartz. Phases occur, however, in which the rock differs in no way from that of the large Dexter Creek body; in others the plagioclase is more calcic and augite is present. An analysis of the rock from the main body above Porphyry Basin, which may be considered as characteristic of most of the rock, is given in the table of analyses.

The small bodies of quartz monzonite porphyry on the divide between Cow and Bear Creeks have an unusually prominent porphyritic texture, due to the size of the phenocrysts. Glassy sanidine occurs variably in crystals 1 or 2 cm. long. Biotite is conspicuous, but augite, which was primarily of equal importance, is greatly decomposed and scarcely noticeable to the naked eye. The groundmass is commonly very evenly granular.

LATITE.

Introduction.

The rocks called latite contain both potash feldspar (orthoclase) and the soda-lime series (plagioclase) as quantitatively the most important constituents, with variable amounts of quartz and one or more of the dark silicates biotite, hornblende, augite, and a rhombic pyroxene. They also exhibit, especially in the groundmass, the textures of surface lavas rather than of intrusives at considerable depth, such as the monzonite porphyry already described. Among the many intrusive masses in the San Juan tuff-agglomerate and more recent surface volcanics the great majority have the composition and texture of quartz latite, but the textural distinction between these rocks and quartz monzonite porphyry can not be sharply drawn in all cases, both because there are many bodies of intermediate position, and because the texture is not exclusively dependent on the horizon of intrusion. Hence some of the rocks called latite might in themselves be as well called monzonite porphyry, but from association and details of composition they belong in one of the latite groups and are so included.

The microscopical study of the various latites shows several groups particularly characterized by their dark constituents and in many places by persistent textural features. As these groups represent beyond much question contemporaneous injections of a given magma their distinction on the map seems desirable. They probably all correspond to lavas of the Potosi volcanic series.

In order to avoid the long terms necessary to express the distinctive mineral characters of these groups they are designated in the legend and in the descriptions by local names, emphasizing also the localities where they are best developed.

Difficulty Creek Latite.

Occurrence.—One of the most clearly defined varieties of porphyritic latite occurs at the upper forks of Cow Creek, where the main stream is joined by Wildhorse Creek and Difficulty Creek. The largest mass is cut by the wild canyon of Difficulty Creek and the variety may be called after that locality. This mass has crosscutting relations to the south, yet its base is conformable, approximately, with the bedding of the San Juan tuff, giving the mass the form of an asymmetric laccolith. Its lateral extension is small and the visible disturbance of the bedded volcanic rocks which it intrudes does not correspond in degree to the size of the mass. In the cliffs west of Difficulty Creek the Potosi tuffs are clearly distorted by the intrusion.

Another mass occurs on the point of the ridge north of Wetterhorn Creek at a level in the San Juan tuff-agglomerate about 2000 feet above the base of the main Difficulty Creek body. The beds which once covered it have been removed by erosion, so that it is not possible to see the disturbance which took place as a result of the intrusion. The lower surface of the body is very uneven and rests upon extremely coarse and poorly consolidated agglomerates. A pronounced columnar structure with the joint planes uniformly at right angles to the contact is a striking feature of this body. It is connected with the lower mass by a dike.

To the west of the Difficulty Creek mass a body of the same rock caps the mountain whose summit is at 12,445 feet. Its base lies at about 12,000 feet. As dikes of the latite cut this body it is probably to be regarded as an earlier intrusion of the same magma.

Still another mass of this latite occurs on the ridge just south of the principal body. Its lower contact is not accurately mapped, as it occurs in inaccessible cliffs.

As shown by the map a considerable number of dikes of the Difficulty Creek latite occur in the immediate vicinity of the main mass and radiate more or less markedly from that center. These are not all exactly of the type of the larger masses but are very closely related.

Description.—There is very little textural or mineral variation to be observed in the rock of different parts of the large bodies, or of the dikes. The color is very light gray or nearly white, in many places with a pink or light-purplish tinge. Phenocrysts of feldspar and biotite lie in a strongly predominant felsitic groundmass. The feldspar phenocrysts consist almost entirely of a sodic plagioclase, most commonly oligoclase, and a very little orthoclase. Biotite and quartz are the only other phenocrysts universally present. Hornblende occurs with biotite in the rock of the 12,445-foot summit west of the Cow Creek forks, and is common in several of the dikes of this region.

The groundmass of the rock from the large body is a very evenly microgranular aggregate of orthoclase and quartz containing a small amount of plagioclase and magnetite dust. The smaller masses and a part of the large one have an equally fine grained groundmass, but the texture is trachytic and the rock contains, in some places, a little glass. Here and there orthoclase and quartz occur in micrographic intergrowth. The varietal character of the rock is expressed by the term quartz-biotite latite.

The analysis of this rock given in the table on page 12 was made from material characteristic of nearly all the observed occurrences. Banded structure is common in contact zones. In some dikes the grain of the groundmass is comparable with that of the monzonite porphyries already described, but it seems best to call all the dikes connected with this center of eruption by the same name.

Cimarron Creek Latite.

The name Cimarron Creek latite is applied to a variety of intrusive rock especially common in the drainage of Cimarron Creek in the Ouray and Lake City quadrangles. The rock is petrographically a quartz-pyroxene latite.

Occurrence and distribution. — The Cimarron Creek latite occurs in many dikes, sills, and irregular intrusive masses, for the most part in the San Juan tuff-agglomerate, but is also present in the Potosi volcanic series, in which it is not everywhere easily distinguishable from flows. Some of the sheets or sills are traceable for several miles at approximately the same horizon, and there are in some localities a number of bodies, now seemingly disconnected, that undoubtedly belong to the same intrusion. The masses vary from but a few feet to hundreds of feet in vertical dimensions. They are most numerous in the Cimarron Creek drainage, but they also occur on the headwaters of Cow Creek, and on the divides toward North Fork of Henson Creek.

Description.—The most common phase of the Cimarron Creek latite is a dark-gray, almost aphanitic rock, with many minute soda-lime feldspar (plagioclase) phenocrysts, 2 mm. or less in diameter. Labradorite and andesine are the prevalent kinds of plagioclase. The ferromagnesian silicates are megascopically hardly visible except where biotite or hornblende is added to the actually more abundant pyroxenes, augite and hypersthene. The hypersthene is very commonly decomposed to chlorite or serpentine; the augite may be entirely fresh, but where decomposed yields calcite as its chief product.

The groundmass of these rocks is either glassy, at least in part, or cryptocrystalline. Where most clearly resolvable into its constituents it is found to consist of orthoclase and quartz with a small amount of augite, magnetite, and apatite. The dark color of the rock is due to the fine magnetite dust of the groundmass, but the total of this mineral is less than 5 per cent, most of it being in microphenocrysts.

The plagioclase of the rock is apparently all developed in phenocrysts, but none of the orthoclase has that development. The habit of the rock is thus strongly andesitic, but as the chemical analysis (given in the table, p. 12) of a typical rock shows, there is nearly or quite half as much potash feldspar as plagioclase, with 10 or 15 per cent of free silica, so that the rock is a quartz latite rather than a quartz andesite or dacite. In the larger bodies the lower contact zone is generally in part a glassy flow breccia with dark vitrophyre fragments in a yellowish or reddish matrix of practically the same material. In these vitreous parts the hypersthene is uniformly fresh and nearly equal to augite in amount. The development of biotite and hornblende is extremely variable, but nearly all masses have a small amount of reddish-brown biotite.

American Flat Latite.

Occurrence.—A variety of latite which it has been thought best to distinguish from the others on the map occurs as an intrusion in the Henson tuff, its largest known body being that of American Flat, on the Silverton-Ouray quadrangle line. This rock so closely resembles some of the lower flows of the Potosi volcanic series that it was taken as the basal flow of that series in mapping the Silverton area, and is so represented in the Silverton folio. Its intrusive character is now evident, being particularly distinct in the Lake City quadrangle near Uncompahgre Peak. The rock is confined to the zone of the Henson tuff and fragments of nearly identical rock are contained in that clastic formation, as has been stated.

Only three areas of this rock are represented on the map. Of these the small tongue at the extreme head of Bear Creek is directly connected with the sheet of American Flat. Another small body appears in contact with Henson tuff and rhyolite porphyry close to the eastern boundary of the quadrangle, north of North Fork of Henson Creek.

Description.—The American Flat latite is a light to dark gray porphyritic rock notable for its glistening biotite leaves, which by their subparallel arrangement express a fluidal texture that appears also in the fracture of the rock. The feldspar phenocrysts are mainly mere specks in the predominant felsitic groundmass. Numerous small rounded and embayed quartz crystals are visible on close scrutiny.

Under the microscope it is apparent that hornblende was once present, but has been resorbed or decomposed, only its outlines, indicated by a few opaque grains, remaining. Plagioclase, principally oligoclase, is abundant in broken crystals, much exceeding the orthoclase in amount. The groundmass is a cryptocrystalline or fine microcrystalline, irregularly granular mixture of orthoclase and quartz. The amount of plagioclase is less than in the other intrusive latite and the rock is unquestionably identical with or very close to the lower Potosi flows designated quartz latite. It is believed that this intrusive type is contemporaneous with some of the Potosi lavas not far above the base of that series.

Other Varieties of Latite.

Among the numerous intrusive latites of the southeastern section of the quadrangle are several varieties notably different from the three already described, but not deemed worthy of distinction on the map. They are allied rocks, presumably equivalent to some Potosi flows. The principal varieties are the following:

Hornblende latite.—This rock, readily distinguishable under the microscope, forms the notable sheet in the east wall of The Amphitheater near Ouray, reappears at the same level (about 11,500 feet) in the valley of Wildhorse Creek, and near the head of Cow Creek east of Wildhorse Peak. A few small bodies occur on either side of Cow Creek and one north of North Fork of Henson Creek. These masses occur so nearly at one general level in the San Juan formation, and in one east-west zone, that they may be plausibly regarded as parts of one main intrusion with a few minor offshoots.

The rock is a dark-gray or reddish, very fine grained porphyry with abundant plagioclase and hornblende phenocrysts in a dense groundmass. The abundant hornblende is in most places wholly altered by resorption, its place being occupied by the well-known mixture of ferritic particles, quartz, orthoclase, etc. But in some specimens the hornblende is very fresh. The groundmass is rich in orthoclase and quartz.

Biotite latite.—The variety of latite which forms the summit of Wildhorse Peak and occurs also in several other masses is a quartz-biotite latite of different habit from the otherwise similar rock of Difficulty Creek. The principal body cuts the older rocks almost on the line between the San Juan tuff-agglomerate and the Henson tuff. It exhibits a steeply northward-dipping fluidal banding, which makes it resemble a tilted series of lava flows. The other prominent bodies form two east-west ridges of jagged crest line situated northeast of Wildhorse Peak. They rise from a mass of landslide débris which covers the contacts effectually.

This rock is reddish, pink, or dark gray in color, with prominent phenocrysts of plagioclase and biotite, that nearly equal in amount a very dense groundmass. The groundmass is extremely fine grained and apparently granular in much of the rock, but the contact zone is in places a black vitrophyre. The plagioclase is mainly andesine or labradorite and its crystals are perfect in shape, few of them being broken as is common in some other intrusives of the region, notably in the adjacent American Flat latite.

Although no analysis has been made of the Wildhorse Peak rock, there can be no doubt that the groundmass is as rich in quartz and orthoclase as the more highly crystalline rocks.

Augite latite.—A rock of distinctive character forms an extensive intrusive sheet which occurs in the valley of Wildhorse Creek at the northwest base of Wildhorse Peak and extends westward into Difficulty Creek and eastward into the head of Cow Creek. It comes into contact with both the Difficulty Creek latite and the hornblende latite. It was not possible to follow this mass connectedly from one gulch to another in the inaccessible cliffs, but it seemed from favorable view points to have the extent represented by the map.

This rock is a pink or gray felsitic porphyry very rich in minute phenocrysts of plagioclase and augite, with rather sporadic hornblende and biotite. Residual grains of quartz phenocrysts surrounded by an aureole of oriented groundmass quartz are characteristic. The groundmass is mainly a patchy micropoikilitic intergrowth of quartz and orthoclase.

Latite at Lake Lenore.—A peculiar rock occurs in two very irregular crosscutting bodies in the sedimentary beds near the mouth of Dexter Creek. One, directly west of Lake Lenore, is nearly circular in form and is not more than 100 yards in diameter. North of the lake is a smaller mass, which, although no actual connection has been found, is believed to be a horizontal or sheetlike apophysis of the crosscutting body. The contacts of the main mass with the sandstones of the Cutler formation, which are exposed at several points, are very irregular and nearly vertical. The rock is dark and dense, and has a fluidal banding that is everywhere parallel to the contact line. Inclusions of sedimentary rocks and of minute grains derived from them are numerous. Another larger body of this rock is intruded in the McElmo formation on the north side of Dexter Creek at an elevation of about 8500 feet and about 300 feet above the stream; this body is in the form of an irregular branching dike.

The rock composing these crosscutting masses is of too dense a texture and too greatly decomposed to permit an altogether satisfactory microscopical determination. It has been grouped, for purposes of mapping, with the latites, but the relative amounts of quartz, potash, and soda-lime feldspar present are very difficult to determine. No fresh ferromagnesian minerals remain.

INTRUSIVE RHYOLITE.

Occurrence.—An irregular crosscutting body of rhyolite porphyry of considerable size and having a still greater extension farther east in the Lake City quadrangle occurs on the north side of North Fork of Henson Creek. It has been intruded partly in the Silverton andesites and tuffs and partly in the Potosi volcanic series and sends out a large number of arms that branch and intrude the older rocks in an extremely complicated manner.

Description.—The rock is nearly white and very fine grained, containing numerous large quartz phenocrysts and small flakes of biotite. The groundmass consists of finely granular quartz and orthoclase, with a very little plagioclase. The phenocrysts are of orthoclase and quartz, with small amounts of biotite and magnetite. The rock is intermediate in texture between a rhyolite and a very fine grained granite porphyry.

INTRUSIVE ANDESITE.

A number of dikes and small intrusive bodies have been distinguished on the map as andesite. Some of them are not far in composition and texture from rocks that have been called latite, but as a group they are characterized by a notable decrease in the amount of orthoclase and quartz. With this decrease plagioclase and augite enter into the groundmass. Several somewhat different varieties might be given special description, but their subordinate development does not warrant full treatment in this place.

Occurrence and distribution.—The largest mass included here occurs as an intrusive sheet in Mancos shale in Nate Creek. It forms bluffs on the north side of the stream. A smaller body occurs on the north side of Nate Creek at the mouth of Devils Canyon. This body probably intrudes San Juan tuff-agglomerate, but the thick mantle of landslide débris all along the base of Cimarron Ridge obscures the relations except in the canyon.

Andesitic dikes are particularly numerous in two localities. In Dike Ridge, the divide between the heads of Middle and West forks of Cimarron Creek, north of Coxcomb Peak, they rib the abrupt slopes of San Juan and Potosi rocks by projecting as high walls visible for miles. Fig. 8 of the illustration sheet shows some of the dikes on the eastern face of Dike Ridge.

On the ridge south of Porphyry Basin several small dikes appear with trends nearly parallel to some of those in Dike Ridge, but their continuity was not established.

Another locality of notable andesite dikes is the ridge west of Difficulty Creek. A radiate arrangement is suggested by the map, but as by no means all dikes are represented this may be deceptive. Some of these dikes extend for miles and in many places project above the crumbling San Juan as high walls. Fig. 5 (illustration sheet) shows one of these walls on the divide at the head of Dexter Creek.

In other parts of the quadrangle single dikes of andesite occur, but many of these are not mapped, the time required to trace them being more than could be given to it.

Description.—The andesites here discussed vary like the latites in the development of their dark silicates — augite, hypersthene, hornblende, and biotite. On the whole, the andesites are richer in these ferromagnesian minerals than the latites, yet none of them is a strongly basic rock. All carry some orthoclase in the groundmass and quartz is its common companion, but in relatively small amount.

The Nate Creek sheet is a brown or yellowish-gray hornblende andesite with a little biotite. Most of the Dike Ridge rocks are hornblende-biotite andesites, but one at least is an augite andesite. Both augite and hypersthene occur in some of the dikes west of Difficulty Creek.

DIABASE DIKES.

Occurrence.—Dikes of diabase occur at two different localities in the Ouray quadrangle. One cuts quartzites of the Uncompahgre formation, but no younger rocks; the other visibly intrudes the Cutler, Dolores, and La Plata formations, and may have reached still higher horizons, but evidence for this has been lost through erosion. The dike in the Algonkian area has been traced from the fault at the box canyon of Canyon Creek, where it disappears beneath the Paleozoic sediments, in a direction south of east for about a mile and a half, not quite to the point where the quartzites are covered by the San Juan tuff. The thickness of the dike averages 50 feet, but is variable from place to place, and near the town reservoir it is fully 150 feet. The dike cutting the Mesozoic rocks is exposed on the east side of the Uncompahgre Valley nearly opposite the mouth of Coal Creek. It has a nearly north-south direction, is from 6 to 8 feet wide, and is exposed for a little over a quarter of a mile from 100 to 300 feet above the bottom of the valley.

Description.—The diabase from the Algonkian area is dark greenish brown, massive, and of a medium texture. Long, thin crystals of labradorite are abundant and easily recognized megascopically and with them augite is associated. In addition to these minerals the microscope shows that magnetite and considerable accessory apatite are present.

The rock from the dike on the east side of the Uncompahgre Valley is black and has a dense, even texture in which individual minerals can not be distinguished. Microscopically this rock is seen to possess the characteristic ophitic texture of a diabase and the usual minerals—labradorite, augite, and magnetite, the last occurring in irregular grains and skeleton crystals. The augite has suffered alteration to chlorite and calcite.

CHEMICAL COMPOSITION OF THE IGNEOUS ROCKS.

The descriptions of the igneous rocks, both intrusive and effusive, show them to be closely related in chemical composition. To illustrate this fact more fully, and for purposes of comparison with rocks from other parts of the San Juan, a few of the freshest and most important types have been analyzed by George Steiger in the chemical laboratory of the Geological Survey, with the results given in the following table.

The analyses demonstrate the close relationship between these rocks that has been brought out in the descriptions. They show with special clearness the contact presence of a large amount of orthoclase and more or less quartz in the extremely fine grained groundmass and justify the reference of the rocks to the latite rather than to the andesite group.

On comparison of the analyses with those published in the Silverton folio it is evident that all the Ouray rocks are intermediate between certain more highly siliceous and alkalic rocks, the rhyolites of the Potosi volcanic series and of some known intrusions, and the pyroxene andesites of the Silverton volcanic series. For a more detailed discussion of the chemical relations of the magmas of the San Juan region the reader is referred to the Silverton folio.

Chemical analyses of rocks of the Ouray quadrangle.

Constituent.	1.	2.	3.	4.
SiO_2	68.81	61.36	60.69	59.83
Al_2O_3	15.54	16.36	15.90	15.86
Fe_2O_3	1.78	3.59	4.52	4.07
FeO	.80	1.45	1.72	2.12
MgO	.52	1.75	1.93	2.73
CaO	2.43	3.59	5.23	4.34
Na_2O	4.24	4.04	3.55	3.00
K_2O	4.07	3.64	3.22	3.55
H_2O-	.50	1.34	.93	1.09
H_2O+	.78	1.56	.96	2.04
TiO_2	.28	.51	.73	.70
ZrO_2	Trace.	Trace.	Trace.	
CO_2	.48	.64	.27	.59
P_2O_5	.13	.36	.31	.31
MnO	.12	.07	.13	.06
BaO	.13	.12	.10	.08
SrO	.04	.12	.03	.02
	100.65	100.50	100.22	100.39

1. Quartz-biotite latite (Difficulty Creek latite). Northern part of intrusive mass between Difficulty and Cow creeks. Fine-grained light-gray porphyry. Has many small phenocrysts of oligoclase and andesine, with some biotite and large magnetite grains, in a groundmass of orthoclase and quartz. A little calcite of secondary origin. Traces of apatite.

2. Quartz monzonite porphyry. Large dike on quadrangle border, east side of Porphyry Basin. Gray or slightly pinkish porphyry. Contains as phenocrysts many small white plagioclase crystals (oligoclase and andesine), biotite, a small amount of green hornblende, and a little quartz, all in a granular groundmass of quartz and orthoclase. Magnetite and apatite as accessories. A little secondary calcite.

3. Quartz-pyroxene latite (Cimarron Creek latite). Arm of intrusive sheet in San Juan formation on east side of Pinnacle Ridge below remnant of Potosi volcanic series. A fine-grained dark-gray rock of andesitic habit, with numerous small megascopic crystals of andesine and labradorite. Dark silicates, mainly augite (fresh) and hypersthene (altered), with a little hornblende and biotite. Groundmass cryptocrystalline, brown from disseminated ferritic specks, and in most distinctly crystalline spots clearly made up chiefly of orthoclase and quartz. Magnetite in fine dust.

4. Quartz-biotite latite (Potosi volcanic series). Point of elevation 13,400 feet on divide 1½ miles north of Wetterhorn Peak. Dark-gray medium-grained porphyry containing many white andesine or labradorite crystals and biotite tablets, with a few crystals of orthoclase and quartz in an aphanitic groundmass. Augite is also an important constituent where the rock is fresh. The strongly fluidal groundmass varies from a coffee-brown glass in contact zones to a microcrystalline aggregate of quartz and orthoclase stained by ferritic particles.

The classification of these rocks by the quantitative system is represented concisely in the table below:

Quantitative classification of Ouray rocks.

	Class.	Order 4. Quardofelic.	Rang. 2. Domalkalic.	Rang. 3. Alkalicalcic.	Subrang 3. Sodipotassic.
1. Quartz-biotite latite (intrusive), Difficulty Creek=toscanose	I	X	X		X
2. Quartz monzonite porphyry=toscanose	I	X	X		X
3. Quartz-pyroxene latite (intrusive) = harzose near amiatose	II	X	X		X
4. Quartz-biotite latite=harzose near amiatose	II	X		X	X

STRUCTURE.

INTRODUCTION.

The structure of the sedimentary and bedded volcanic rocks of the Ouray quadrangle is relatively simple throughout the greater part of the area, but in the vicinity of the town of Ouray more complex structures are found, and the movements that they represent have an important bearing on the stratigraphy of the whole San Juan region. Five periods may be recognized during which deformation took place, affecting all the beds to a greater or less degree, and the resulting structures may be described best by beginning with the youngest and simplest.

The broad structural features of the San Juan Mountains have been outlined in the introduction of this folio, and the features analyzed in greater detail at this point are the elements which taken together make up the composite domal structure of the San Juan region.

In this section the structure only is described, its stratigraphical significance being discussed under the heading "Historical geology."

STRUCTURE OF THE TELLURIDE CONGLOMERATE AND THE BEDDED VOLCANIC ROCKS.

Except where affected by faults, which are described in a later paragraph, the Telluride conglomerate and the bedded volcanic rocks above it have been disturbed but little since the time of their deposition. In the Telluride and Silverton quadrangles the conglomerate has a slight but definite inclination to the east. Although not easily recognized on account of the discontinuity of the beds, the same tilting is shown in the Ouray quadrangle, the inclination here being to the northeast.

STRUCTURE OF THE MESOZOIC FORMATIONS.

Generally throughout the southern and western San Juan Mountains all the Mesozoic beds appear to be conformable from the base of the Dolores upward. These relations are well shown in the Uncompahgre Valley, where the Cutler beds as well as the Mesozoic formations have a low northwesterly dip. Just north of Cutler Creek they are affected by a gentle monoclinal fold which carries all but the Mancos successively below the level of the Uncompahgre flood plain; this structure is shown in section A–A. To the east, in Cow Creek, where the sediments are again exposed beneath the volcanics, the same monocline, slightly sharper, may be observed. Elsewhere in the quadrangle a moderate northwesterly dip characterizes the Mesozoic rocks except in the extreme north, where the Dakota has a northeasterly inclination.

A discordance at the base of the La Plata is known to exist to the northeast and actual evidence of it is to be seen in this quadrangle along Cow Creek, where the La Plata rests, not upon the Dolores, but upon the Cutler formation. Although this unconformity is an indication of deformation preceding the La Plata and following the Dolores, the movements, so far as they are recorded within the area of the Ouray quadrangle, were relatively slight as compared with those which affected all the Mesozoic formations, and consisted in a very moderate westward tilting, starting at some point between Cow Creek and the Uncompahgre and now obscured by the volcanics. Section C–C brings out these relations and also shows the unconformity at the base of the Telluride.

STRUCTURE OF THE PALEOZOIC FORMATIONS.

The region of most pronounced deformation in the Ouray quadrangle is that bordering Canyon Creek and Uncompahgre River south of Corbett Creek. Northward from the exposures of the Ouray and Hermosa that lie west of the Uncompahgre at the southern border of the quadrangle, the Paleozoic rocks have a general northerly or northwesterly dip that is evident from a number of points of view near Ouray. This structure is principally of pre-Triassic—i. e., pre-Dolores—age, but was accentuated by later uplifts of the same general character. Minor structures of a less simple nature, also pre-Triassic, occur at two different localities and call for special description. The first to be noted is that best displayed by the older Paleozoic rocks south of Oak Creek. When the Ouray limestone is followed northward on the bench above the Uncompahgre, it is found to have a moderate inclination slightly north of west, until, beyond the small east-west fault about one-half mile north of the quadrangle boundary the dip becomes nearly northwest and increases to 25° or 30°, carrying the Ouray limestone to the level of Canyon Creek and representing a drop of nearly 1000 feet in a mile. To disregard, for the moment, the northwest-southeast fault crossing Canyon Creek a short distance above its mouth, the northwest inclination of the beds continues, with slight variations in the angle of dip, to Oak Creek, beyond which the dips swing more to the north and are of a lower angle. Southwest of Oak Creek the Hermosa beds have a northwest dip of decreasing angle to the southern boundary of the quadrangle.

The structure north of Ouray is admirably shown in the rocky walls that border the Uncompahgre almost as far as the mouth of Corbett Creek (fig. 9). West of the river the Hermosa formation and a thin remnant of the Cutler beds preserved beneath the unconformable Dolores have a dip of 10° or 15° N., which continues for about one-half mile northward, to a point where the beds, influenced by a sharp monoclinal fold, with an axis slightly north of west, dip to the north at an angle of more than 35°. (See structure section A–A.) This dip is sufficient to carry the Hermosa beds below the level of the valley within a quarter of a mile of the point where the south limb of the monocline begins, and thence northward the only beds of the Paleozoic section exposed are those of the Cutler formation. Just above the point where the valley begins to widen near the mouth of Corbett Creek the Cutler beds return to a very moderate northerly or northwesterly dip and assume nearly conformable relations with the overlying Dolores. East of the river precisely the same structure (section B–B) may be made out, except that in places in the region between Cascade and Bridalveil creeks it is much obscured by the metamorphism of the rocks; local upturning has also taken place in the vicinity of the large body of intrusive porphyry south of Bridalveil Creek. From the point of Cascade Mountain southeastward to The Amphitheater the influence of the Canyon Creek monocline may be observed in the 10°–15° NW. dip of the Hermosa beds. This structure accounts for a slightly greater elevation of certain horizons of the Hermosa on the east of Uncompahgre River just north of Cascade Creek.

Summarized briefly, the Paleozoic rocks near Ouray have a gentle northwesterly inclination that is complicated by two monoclinal folds whose axes lie at an angle of 45° to one another.

Another instance of the structure resulting from the pre-Triassic movements is found in the occurrence of Ouray limestone on Cow Creek. Although completely surrounded by a thick cover of landslide débris, the relations of this exposure to near-by outcrops of the Cutler and La Plata formations seem to show that it is part of a block faulted upward during the pre-Triassic movements. Simple folding can not account for the position of the Ouray, because the beds of the Cutler formation, exposed less than 200 feet above the Ouray to the east, are nearly horizontal, whereas the Ouray strata dip 45° SW. To the west and 200 feet above the Ouray the La Plata is exposed with a southwest dip of 30°. The faults supposed to bound this mass must be regarded as older than the La Plata and probably antedated the Dolores, although the absence of this formation here, due to the La Plata unconformity, makes it impossible to assert this definitely. No movements comparable in magnitude to this faulting have been recognized in the La Plata in other parts of this region, and it seems justifiable to correlate the Cow Creek faulting with the period at which the folding occurred near Ouray.

The movements recorded by the Mesozoic rocks also affected the Paleozoic formations, but they can not be recognized in the region of more complex deformation, although evident in other places where apparently conformable relations exist between the Paleozoic and Mesozoic rocks.

ALGONKIAN STRUCTURE.

So far as the exposures within the Ouray quadrangle are concerned the quartzites and slates of the Uncompahgre formation have a simple structure. From the southern boundary of the quadrangle northward to the fault near the mouth of Canyon Creek, where the exposures end against Paleozoic rocks, the beds have a dip of 45° to 65° in a direction west of north on the west side of Uncompahgre River, and north or slightly east of north east of the river. If we assume, as seems probable, that the upper limits of the formation are to the north, the structure of the beds is that of an anticline pitching steeply to the north. Further evidence for this is found in the southward extension of the beds in the Silverton quadrangle, where their attitude appears to be that of an elongated domal uplift. Minor irregularities or plications may occur, especially in the slates, but great uniformity prevails. Section B–B shows the general attitude of the beds and the relation of younger formations to them. The northerly dip of the Paleozoic rocks, due to structures previously described, shows that a part at least of the inclination of the Uncompahgre strata belongs to the later period of deformation, and still younger movements, recorded elsewhere in the region, have undoubtedly exerted some influence on the Algonkian, but the results are obscured by the greater complexity of the older structures.

As has been pointed out in describing the formation, the metamorphism of the Uncompahgre strata is to be ascribed to regional dynamic processes and not to contact relations with granitic masses.

FAULTS.

In only two areas in the quadrangle has faulting occurred to any marked degree. One of these is in the vicinity of Ouray and the other in the northwest corner of the quadrangle, examples of both being shown in section A–A. The faulting in the vicinity of Ouray is younger than the volcanic rocks. The most pronounced fault of this region is the one which extends from the southern side of The Amphitheater northwestward to Oak Creek. The downthrow is to the north and at the point where it crosses Canyon Creek amounts to about 300 feet. As shown by the geological map its eastern extension is lost in the San Juan tuff. To the west the fault is represented as dying out in the McElmo shales on the south side of Oak Creek; it is clearly seen to dislocate the La Plata formation and sheets of porphyry, but the Dakota is apparently unaffected. A northwest fault, branching to the southeast, occurs on the north side of Oak Creek. It is of apparently the same age as the longer fault to the south, since it also causes a break in the porphyry sheets. The older Paleozoic rocks lying on the bench west of Uncompahgre River have been dropped 150 feet to the north by a fault having a direction slightly north of east, which disappears within a short distance on passing into the Hermosa to the west and the Uncompahgre slates to the east. Although these are the only faults in this region of sufficient magnitude to be represented on the map, a very large number of minor dislocations are found in the neighborhood of Ouray. These are discussed by Mr. Irving in connection with the ore deposits in the section on economic geology.

The faults of the northwest area are of a more pronounced character. They belong to a definite system having a general northeasterly direction, and in each the strata have been elevated on the northwest. The greatest of these faults is the one crossing the Uncompahgre just north of the great moraine; it was noted by Peale and shown on the Hayden map, though not given the usual special representation. As a result of this fault the Dakota formation reappears and is exposed in the hills east of Dallas. Within a short distance the local easterly dip carries the Dakota below the surface and it is impossible to trace the fault in the soft Mancos shale, but it is believed to be responsible for the difference of nearly 1000 feet that exists between the elevation of the Telluride conglomerate at the head of Nate Creek and that of exposures of the same formation at the head of North Fork of Lou Creek. In this region solid-rock formations are much obscured by landslide débris and drift and the exact location of this fault can not be determined; its representation on the map is purely hypothetical. West of the Ouray quadrangle the fault has been traced for more than 10 miles, its general position being well marked by the McElmo and Dakota escarpment on the north side of the valley of Dallas Creek. There is no means of accurately measuring the displacement due to this fault, since the depth at which the top of the Dakota lies beneath the surface on the south side of the fault is unknown. The Dakota in the top of the mesa north of Dallas Creek is nearly 1000 feet above the valley, which is composed of Mancos shale, and a minimum displacement of 1000 feet must be allowed; this corresponds with that indicated by the Telluride conglomerate to the east.

The smaller faults to the north have throws of 100 or 200 feet, but are evident only where the Dakota sandstone is exposed. The most northerly one crosses Uncompahgre River and is shown in the cliffs on the west side; the others are lost under the valley alluvium or in the Mancos shale.

The relation between the faults and folds of the Ouray quadrangle is not clearly determinable. It is assumed, however, that the faults of the Ouray area, like most of those in the broader San Juan region, are Tertiary and are not related to the folds of the pre-Tertiary sediments which have been discussed. This statement is based on observation in many localities that faults cut both volcanics and older sediments, whereas faults clearly connected with the folding of pre-Tertiary strata are very rare.

AREAL GEOLOGY.

INTRODUCTION.

The leading geological features of the Ouray quadrangle belong to four distinct areas, which are well suited to purposes of description. The upper Uncompahgre Valley and the region of low relief in the northwestern portion of the quadrangle constitute two of these divisions and in them the sedimentary formations are those which call for special consideration. The two other areas are the upper part of Cow Creek valley and the region along the eastern border of the quadrangle, including North Fork of Henson Creek and Cimarron Ridge. These last two areas are occupied almost exclusively by volcanic rocks.

UPPER UNCOMPAHGRE VALLEY.

The geology in the vicinity of Ouray is more complex than that of any other part of the quadrangle, and although the structural and stratigraphic features are the most important, nearly all the various elements characteristic of the geology of the other areas are present.

Uncompahgre River enters the quadrangle through a canyon whose walls are composed of the quartzites and slates of the Uncompahgre formation. The quartzites extend upward for nearly 2000 feet above the river and their upturned edges are covered unconformably by 2000 feet or more of the San Juan formation. West of the canyon the oldest Paleozoic rocks occupy a bench about 1000 feet above the river; the San Juan and a thin band of Telluride conglomerate here rest upon the Hermosa formation. A northwesterly dip carries the Molas, Ouray, and Elbert formations down to the level of Canyon Creek, where a fault farther lowers them, until, at Ouray, the continuing dip carries them below the floor of the valley.

East and west of Ouray rise abrupt cliffs that for 1200 feet are composed of beds of the Hermosa formation having a northerly dip. These are sharply truncated by the unconformable Dolores formation, as may be seen from many points of view to the west. The northerly dip of the Carboniferous rocks, which near the mouth of Bridalveil Creek develops into a sharp monoclinal fold, causes the Hermosa beds to disappear at a point a little more than a mile north of Ouray. The Cutler formation, consisting of bright-red strata, which, on account of the Dolores unconformity, disappear or are reduced to a few thin layers in the vicinity of Cascade and Oak creeks, assumes apparently conformable relations with the Dolores north of Corbett Creek and forms the lower slopes of the Uncompahgre for more than 4 miles.

North of Dexter Creek, on the east side of the river, the younger sedimentary rocks appear to advantage, the nearly white La Plata sandstone standing out in sharp contrast above the red beds of the Triassic and Permian, and the Dakota quartzites forming a nearly continuous escarpment above the gentler slopes of the McElmo shales. North of Coal Creek an increase in the northerly dip carries the Dakota lower and lower until the soft shales of the Mancos formation cover it and mark the beginning of the northwestern area.

The western side of the Uncompahgre Valley has comparatively few exposures of bare rock, much more of the surface than is represented on the map being covered with either landslide débris or drift.

The region bounded roughly by Corbett and Dexter creeks on the north and Oak and Cascade creeks on the south is noteworthy because of the number of bodies of monzonite porphyry which as dikes, sheets, or laccoliths, have been intruded at different horizons of the sedimentary rocks and the San Juan tuffs. The two largest bodies are those in Dexter Creek and on the end of the ridge between Oak Creek and Corbett Creek. The prominent cliff of porphyry above the American Nettie mine belongs to the Dexter Creek body. Another body of laccolithic character is the one northwest of Canyon Creek at the southern boundary of the quadrangle. Two sheets extending northward from this mass cross Oak Creek and appear in the cliffs west of Ouray, where other thin sheets and dikes are numerous.

One of the most striking spots near Ouray is the region of highly colored and decomposed rocks, locally known as "the blowout," in the gulch directly south of Bridalveil Creek, where a large body of porphyry with numerous apophyses has cut through various horizons of the sedimentary rocks from the Carboniferous to the Dakota (Cretaceous) and all have been extensively metamorphosed, as indicated by the brilliant red and yellow coloring.

In the southwestern portion of the quadrangle the San Juan formation has its greatest known development in thickness, more than 3000 feet being present in the walls of The Amphitheater. The main mass of Whitehouse Mountain is also composed of the San Juan, the cliffs of the upper 1000 alone being due to the massive flows of the Potosi volcanic series with a thin band of Silverton andesite between them and the San Juan.

A description of the geologic features of the southwestern region would be incomplete without a reference to the accumulations of landslide débris that cover about one-fifth of this area. The huge piles of débris resting upon the floor of The Amphitheater are particularly impressive, possibly because the houses of the town of Ouray, lying at the foot of the slide, supply a scale with which the mass of débris may be compared. Other noteworthy landslide areas are in Canyon Creek and Corbett Creek, and the greater part of the ridge between Coal Creek and Uncompahgre River is covered with landslide materials.

NORTHWESTERN AREA.

The northwestern part of the quadrangle, bounded on the east and south by Cimarron Ridge, Ramshorn Ridge, and Baldy Peak, is a region of comparatively low relief in which the soft black or gray shales of the Mancos formation predominate. The smooth, rounded slopes of the hills and the heavy adobe soil are characteristic of areas occupied by the easily eroded clays of the Mancos formation and actual outcrops are rare.

Through a nearly east-west fault, which clearly manifests itself about 1 mile south of Dallas, the Dakota and the upper part of the McElmo formation reappear on its northern side and are well exposed in a number of the low hills and mesas on the east bank of the Uncompahgre, although several small northeasterly faults cause breaks in the continuity of the beds; not far to the west a moderate dip carries them below the Mancos shale. West of Uncompahgre River the Dakota forms the top of a plateau which extends westward for many miles with a gently rolling surface. A short tongue of this plateau just enters the quadrangle at the western border. At a few points impure seams of coal have been opened in the sides of the mesa. They occur about the middle of the Dakota formation and are of no commercial value.

Somewhat more promising coal deposits of higher horizon occur near the head of North Fork of Lou Creek and extensive openings have been made in them about the head of Burro Creek, 2 miles north of the quadrangle. These deposits occur near the base of the Mesaverde formation.

A sheet of andesite porphyry, intrusive in the Mancos shale, forms sharp cliffs on the north side of Nate Creek and also in the Owl Creek drainage, where it lies beneath the Telluride conglomerate. A body of similar rock outcrops at a few places in the midst of landslide débris in the vicinity of Devils Canyon.

Pleistocene deposits are abundant in all parts of this area, the most striking being the great terminal moraine which crosses the Uncompahgre south of Dallas, fully one-half of it lying beyond the boundary of the quadrangle. The slopes northeast of Cow Creek in the Deer Creek drainage are covered thickly with old drift, and west of Cow Creek near its mouth Pleistocene stream gravels cap the mesas and low hills.

UPPER VALLEY OF COW CREEK.

The laccolith of quartz monzonite porphyry, a part of which forms Ramshorn Ridge, marks the lower end of the canyon of Cow Creek. Above this point Cow Creek and its tributaries flow in wild gorges, difficult of access, carved in the agglomerates and tuffs of the San Juan formation, which weather in fantastic columns and pinnacles. Between Wildhorse Creek and the west fork of Cow Creek, now called Difficulty Creek, is a large body of intrusive porphyry from which a number of dikes radiate; another body of similar rock caps the ridge north of Wetterhorn Creek.

The headwaters of Cow Creek and its principal tributaries are in rugged basins above timber line. The steep slopes with hoodoo forms, prevailing in most places where the San Juan formation is exposed, are modified by numerous dikes that stand out as walls in many localities and by the ledges or other projections resulting where intrusive sheets or irregular masses of latite cut the San Juan. Landslides and rock streams also modify the valley walls, but in the opposite sense, tending to lessen the angularity and produce gentler slopes.

The extreme heads of Cow and Wildhorse creeks have cut back across the boundary of the San Juan into the soft Henson tuff and have there excavated basins of gentle relief contrasting with the gorges below. The divide at the head of Cow Creek contains remnants of the Potosi volcanic series. Wetterhorn Peak, the highest summit of the quadrangle (14,020 feet), is composed of an unusually massive rock referred to that series. Beyond the divide, in the extreme southeast corner of the quadrangle, is the head of North Fork of Henson Creek, which is carved deep in the lavas and tuffs of the Silverton series, revealing details of geology quite unlike those of the remainder of the quadrangle.

Between Oban Creek and Ramshorn Ridge, Cow Creek flows through a canyon whose lower walls are composed of the bright-red beds of the Cutler formation. On the west side of the canyon the Cutler is covered unconformably by the La Plata formation, the Dolores and an unknown portion of the Cutler having been removed by pre-Jurassic erosion. To the east the La Plata itself is cut off by the unconformable Telluride conglomerate. Between Red Creek and Oban Creek landslide débris occupies the lower slopes and bottom of the canyon except at a point about one-half mile north of Oban Creek, where there is an isolated outcrop of southwestward-dipping Ouray limestone. This is completely surrounded by landslide débris, and, although clearly a faulted block, its actual contacts with the younger sediments are unknown and the significance of its structure can not be made out.

EASTERN AREA.

The eastern zone of the quadrangle is characterized by the long north-south ridges separating the Cimarron and Uncompahgre waters and the three parallel forks of Cimarron Creek. These ridges are almost wholly made up of the San Juan deposits and exhibit in most typical development the topographic detail characteristic of that formation where it is comparatively little altered and indurated. West and Middle forks of Cimarron Creek flow in U-shaped glacial valleys and their steep walls have been carved into a wonderful labyrinth of turreted and pinnacled forms, capped at many points by huge blocks of the agglomerate. To these features are due the names applied to the ridges. Even the topographic map is able to express something of the character, owing to the many towers represented by closed contours. Toward the heads of the streams the number of intrusive masses increases, modifying the detail as in Cow Creek. The view shown in fig. 8 (illustration sheet) shows Dike Ridge with its precipitous cliffs ribbed by dike walls.

In the northeast corner of the quadrangle is a small area representative of the plateau country that is more prominent farther east in the Lake City quadrangle. The gently undulating surface is common where the surface flows of the Potosi formation have any considerable lateral extent. In this case the San Juan forms Park Mesa, but the horizon of the Potosi is just above it. The shallow drainage courses of Park Mesa are stretches of beautiful meadow fringed by dense growths of spruce and fir.

The lower parts of Middle and West forks and Cimarron Creek itself are covered with a thick mantle of drift, landslide débris, and vegetation, which effectually conceal the Mancos or Mesaverde rocks that might reasonably be expected to appear beneath the volcanics near the northern border of the quadrangle.

HISTORICAL GEOLOGY.

Although certain events in the geological history of the San Juan region, outlined in the introduction to this folio, are not recorded in the Ouray quadrangle, others and especially those which occurred during Mesozoic and Quaternary time, are illustrated better than in any other district. The earliest records preserved in the Ouray region are concerned with late Algonkian time, and in order to make their meaning clear the events which preceded them, as shown in near-by regions, are briefly summarized. In chronicling the closing events of Mesozoic time recourse must be had also to the more complete history of the sedimentary formations as presented in the Durango quadrangle and adjoining territory. The volcanic history of the region differs in no essential feature from that of the Telluride and Silverton quadrangles, although the influence of local conditions is apparent in both the character and extent of the products of different eruptions. Much information relating to Pleistocene and Recent history has been obtained in the course of surveying the Ouray quadrangle, and its bearing on the recent physiographic development of the San Juan region is briefly discussed.

PRE-PALEOZOIC HISTORY.

Archean schists.—The oldest rocks that are known to occur in the San Juan Mountains are schists and gneisses exposed in the Animas Canyon and elsewhere in the Silverton and Needle Mountains quadrangles. They are believed to be of Archean age, but little is known of their origin or of the events which followed their formation more than that they underwent great dynamic metamorphism and were extensively eroded before Algonkian time.

Algonkian rocks.—The destruction of the Archean rocks supplied material for the great thickness of probable Algonkian sediments represented in the Needle Mountains and in part in the canyon of Uncompahgre River near Ouray. Sedimentation was not continuous, and from time to time intrusions of igneous rocks occurred, resulting in a complex of greenstones, conglomerates, quartzites, and slates having a maximum observed thickness in the Needle Mountains of more than 12,000 feet. The older greenstones and conglomerates are not now exposed in the Ouray region, but evidence of their former existence is found in the abundance of pebbles and bowlders, derived in all probability from these rocks, which occur in conglomerates of the Cutler formation.

Granitic and other intrusions.—Many of the large bodies of granular rock occurring in the Needle Mountains and elsewhere are now known to be younger than the Uncompahgre formation but older than the first Paleozoic sediments; they are unchanged in their texture, except in comparatively minor degree, and can not have undergone such complex folding and faulting as that to which the Uncompahgre series had been subjected. No granite occurs in the Ouray quadrangle, but a small body, intrusive in the quartzites, is exposed a short distance to the south, in the Silverton quadrangle, and granite pebbles are common in the conglomerates of the Cutler formation.

Post-Algonkian interval.—A very long period elapsed after the Uncompahgre formation was deposited before the next sediments now known, the Ignacio quartzites and shales, were laid down. Apparently the region was a land area until the Ignacio epoch, which is tentatively thought to be Saratogan (Upper Cambrian). The events of that long period of which we have evidence may be grouped as orogenic movement, metamorphism, intrusion of granite and other rocks, and erosion.

The orogenic movements by which the gneisses and quartzites were brought into approximately their present relations were certainly of great magnitude. So much area is covered by the volcanics that little detail of this structure is visible. The main result was a steep upturning by faulting or folding, so that the subsequent erosion separated the two quartzite areas of the Uncompahgre Canyon and the Needle Mountains by a schist zone, a part of which is seen south of Silverton. This general effect would be produced by an east-west anticline passing through the Silverton quadrangle, the crest being eroded. That this was a simple fold is not probable, since the Uncompahgre sediments of the Needle Mountains exhibit a complex synclinorium largely bounded by faults. The domal folding in the Uncompahgre Canyon is probably a comparatively local feature.

The induration and general metamorphism producing quartzites and slates out of the Algonkian sediments is plausibly to be connected with the period of folding and faulting, although the production of chiastolite in the slates is readily explainable as a contact phenomenon of the granitic intrusion. This mineral is developed in notable degree at few places except in the Needle Mountains.

The erosion by which the basin later occupied by the Ignacio sea was produced can be safely called enormous in its amount, and yet we have no means of determining its extent. It produced a surface, now seen at the base of the Ignacio quartzite, of but very gentle undulations and unevenness as far as it has been studied. For this region the erosive interval was closed with the subsidence that formed the body of water in which these earliest known Paleozoic strata were deposited.

EVENTS OF PALEOZOIC AND MESOZOIC TIME.

The history of the Ouray district during the Paleozoic and Mesozoic eras was in almost all respects that of the San Juan region generally, and the record is found mainly in the sedimentary rocks. Concerning this history little can here be said in addition to the statements made in the introductory sketch except in regard to the Dolores formation and to the unconformity at its base.

Paleozoic history.—The fact that the Ignacio is absent in the Uncompahgre Canyon section, although known to be present on Cow Creek, may indicate either nondeposition or an interval of erosion between the Ignacio and the Elbert, but of this there is no definite knowledge. Elsewhere the Ignacio is followed with apparent conformity by the Elbert, but the absence of rocks of ages intermediate between the Ignacio (Cambrian) and the Elbert (Devonian) must represent a definite interval of which no records are preserved. Beginning with the Elbert the geological history of the region becomes more clear. Sedimentation continued in quiet waters until Mississippian time, when the upper part of the Ouray was deposited; then a change in conditions caused a more or less complete destruction of the upper part of the Ouray and the redeposition of some of the detritus derived from it as the Molas formation, the earliest sediment of the Pennsylvanian epoch. The Molas marks the beginning of a very long epoch of continuous deposition, during the earlier part of which limestones were formed, but in decreasing amounts as time went on, giving way to clays and sands. No marked change from the sandstones of the Hermosa to those of the Cutler can be noted except in the degree of coarseness of the Cutler rocks. The abundance of coarse conglomerates, grits, and cross-bedded sandstones and the lack of continuity in individual horizons indicate that the Cutler in the Ouray region was of fluviatile origin or at most laid down in shallow, turbulent waters. It is not known how long Paleozoic sedimentation continued after the time of which records are preserved in the Ouray region.

The Dolores unconformity.—The interval of deformation and erosion which immediately preceded the Triassic and which is so strikingly indicated by the unconformable relations of the Dolores to the older beds in the cliff exposures near Ouray is an event heretofore unrecognized in the history of the San Juan region and its significance is at present only partly understood. At Ouray the Cutler is the youngest of the pre-Dolores formations preserved, but its apparent conformity with the Triassic everywhere noted, except in the vicinity of Ouray, is far from offering conclusive proof that still higher horizons did not exist before the time of pre-Dolores erosion.

Further discussion of this problem, however, as well as of those connected with the later formations, is not justified here on account of the incompleteness of the sedimentary section. The sedimentary sequence above the Dolores was completed in this region, as elsewhere in the San Juan, by the deposition of the Jurassic and Cretaceous formations following another interval of uplift and erosion. In this interval, which occurred just before the deposition of the La Plata, the Dolores and lower formations were removed on the east by erosion, so that when the La Plata was at last laid down, its base rested to the west upon the Dolores and to the east upon pre-Cambrian schists.

A realization of the thickness of the sedimentary section at the close of the cycle of Upper Cretaceous deposition is necessary to a comprehension of the events next to be considered. It is reasonable to assume that the formations present on the north slope of the San Juan Mountains once had the development they now exhibit in the Animas Valley, on the south side, where they aggregate nearly 12,000 feet in thickness. With the close of the Laramie proper, this region was involved in a great orogenic movement, and the erosion began which produced the pre-Telluride peneplain and the adjacent area of more rugged topography.

TERTIARY HISTORY.

PREVOLCANIC INTERVAL.

Between the cessation of Laramie sedimentation and the deposition of the San Juan tuffs, which are made up of débris from the earliest lavas of the volcanic series, there was continental uplift of the whole region, permitting erosion of the entire section of sediments. As there is no evidence of further aqueous deposition on a large scale in this region, it may be said that the erosion period has extended to the present time. In this immediate area, however, the only product of that erosion, aside from recent detritus, is the conglomerate which underlies the lowest tuffs, the Telluride formation.

Post-Laramie movement.—The uplift that terminated Laramie sedimentation in the San Juan region was undoubtedly the broad continental uplift that embraced the whole Rocky Mountain province, perhaps with local structural centers. One of these was in the San Juan Mountains and its main result appears to have been a broad anticlinal fold with an east-west axis, part of the northern limb of which lies in the Ouray quadrangle.

Post-Laramie erosion and the resultant surface.—It is to be assumed that erosion began with the retreat of the Laramie sea and continued after the elevation of the land ceased. It is not known to what sea the detritus of this erosion was carried to form new sediments; only the result of the long period of degradation can now be seen, and that over a limited area. The surface on which the Telluride conglomerate rests affords the measure of the post-Laramie erosion.

At the southern boundary of the Ouray quadrangle the erosion amounted to the removal of all the Cretaceous and Jurassic sediments and a small amount of older strata, remaining after the pre-Jurassic denudation. To the east it was more; to the west, less.

The surface resulting from this enormous erosion was a gently undulating plain—a peneplain—from the line of Animas and Uncompahgre rivers westward. It is known to have had this character southwest of the Silverton quadrangle, and similar conditions prevailed from Cutler and Oban creeks northward, beyond the boundary of the Ouray quadrangle, to the locality where the conglomerates of the Telluride rest upon the Mesaverde formation.

The pre-Telluride erosion produced a planation of the domal or anticlinal uplift previously discussed, and at the resulting surface the various sedimentary formations must, therefore, have outcropped in more or less concentric zones that were rendered irregular in detail by minor structures of which little evidence is now visible. A central region of considerable elevation and bold relief, where erosion was still active through the time that the Telluride conglomerate was being deposited, lay to the east of the pre-Telluride surface as now recognized, and this region, consisting of the older Paleozoic sediments and Algonkian and Archean rocks, supplied the material for the Telluride conglomerate. The eastward limit of the Telluride conglomerate on the northern flanks of the San Juan Mountains is not known, and the elevated area may have been at least partially surrounded by a lower region in which deposition took place.

Formation of the Telluride conglomerate.—The coarse texture of the Telluride deposits in the Ouray quadrangle and the apparent lack of continuity indicate that they lie close to their source of supply and that they were laid down by streams. In the southwestern part of the Telluride quadrangle the formation is 1000 feet thick and consists of much finer materials, favoring the opinion expressed in the Telluride folio that the deposits were laid down in a shallow lake. It now seems clear that the formation is to be regarded as in part of lacustrine and in part of fluviatile origin. The land area, still containing remnants of the older Paleozoic rocks, must have extended from the Needle Mountains as far north as the canyon of the Uncompahgre, and from this more elevated region many streams flowed out over the lowlands to the west and north, depositing the coarser part of their loads of land waste first in the form of broad flood plains, which gradually merged into one another as grades became less and distances from the highlands increased. Ultimately the streams probably emptied into a shallow lake where fine sands and silts were deposited.

Post-Telluride erosion.—From the apparent conformability of the Telluride and San Juan formations in the Telluride quadrangle it would appear that the deposition of the breccias, tuffs, etc., followed closely that of the conglomerates without any interval of erosion. It was found in the Silverton quadrangle, however, that the San Juan there rests upon an extremely rugged surface, lying in many places at elevations much lower than the Telluride conglomerate, indicating that here at least an interval of active erosion occurred between the Telluride and San Juan. It is probable that this erosion began while the Telluride was still being deposited and it developed a topography, comparable in its relief to that of the present day, before the appearance of the first volcanic rocks. No direct evidence for this is found in the Ouray quadrangle, since the absence of the Telluride beneath the San Juan at many points east of the Uncompahgre may well be explained by lack of deposition. The general elevation at which the San Juan occurs east of the Uncompahgre Canyon, where it rests upon a rugged Algonkian surface, is above that of the Telluride to the west and directly opposite. This surface is believed to be a remnant of the Telluride uplands modified, perhaps, by post-Telluride erosion from the east.

VOLCANIC ACTIVITY.

A complete record of the volcanic history of the San Juan region is not preserved in any of the quadrangles surveyed thus far. Each new area examined throws some light on particular parts of the problem and the relations of the volcanic rocks in the southern part of the Ouray quadrangle are especially significant.

Earliest eruptions.—The San Juan formation is made up of the débris from a huge accumulation of earlier lavas. None of these products of the first period of volcanic activity is known except through its fragments in the San Juan tuff-agglomerate.

The rocks of the San Juan formation so far examined are andesites and latites. The diversity of rock types in this formation is probably no greater than that exhibited by the lavas of the Potosi series, and it is worthy of note that many of the San Juan fragments are very similar to certain lavas of the Potosi.

No direct evidence as to the location of this earliest center of eruption is known, and yet it can not be assumed that its lavas were wholly destroyed in the formation of the San Juan. The vast bulk of the latter deposits indicates that the volcanic pile from which the materials were derived must have been of huge dimensions. The texture and structure of the San Juan do not point to any particular location for the source of its materials. Variations in texture, in the size of fragments, or in regularity of bedding are greater between the beds of adjacent localities than between those of widely separated districts.

Deposition and erosion of the San Juan.—The source of the San Juan materials being unknown, the method of their transportation and deposition remains a problem. That they owe their present distribution in some measure to eruptions of great explosive violence is probable, and that they were in part laid down beneath a lake more or less coextensive with the Telluride lake is undoubtedly true, but a very large part, probably including all of the formation lying in the Ouray quadrangle, was more likely of direct subaerial deposition, possibly influenced by contemporaneous fluviatile action. The reason for this opinion lies in the fact that the Telluride of the Ouray quadrangle is in thin, discontinuous deposits most plausibly of fluviatile origin, and that the lake if present at all, was represented only by shallow estuaries.

As to the original thickness and distribution of the San Juan little is known, since it has been subjected to erosion from its first deposition more or less continuously to the present time. The 3000 feet preserved east of The Amphitheater near

Ouray represents the greatest observed thickness, but at this point Potosi flows rest directly upon it, and it must be assumed that a considerable amount of the San Juan had been removed during the Silverton volcanic epoch.

There is no evidence of extensive erosion during the period that the San Juan tuffs were forming, but between the close of the San Juan eruptions and the beginning of the Silverton epoch the San Juan was vigorously attacked by streams from the east, the formation farther east being apparently unaffected and covered conformably by later eruptives. The best evidence for this is seen in the vicinity of North Fork of Henson Creek and near the head of the north branch of Bear Creek, where andesite flows from the uppermost tuffs of the Silverton series abut against very steep walls of the San Juan. This seems to show that the basin occupied by the Silverton lavas was bounded on the north by a mountain wall of the San Juan. The basin was several thousand feet deep and this is an approximate measure of the erosion to which the San Juan was subject before the first lavas of the Silverton series were poured out. In the Silverton quadrangle more definite records are preserved of this erosion in areas where deep valleys were carved, to be later filled by the flows and tuffs of the Silverton series.

Eruptions of the Silverton series.—Records of the Silverton volcanic epoch are incomplete in the Ouray quadrangle; but, as has been shown in the Silverton folio, a succession of lavas and tuffs more than 3000 feet in thickness was accumulated in the lower country within a few miles south of the Ouray quadrangle. Some idea of the sequence of Silverton lavas has been given in this folio, but the three formations of the series occurring in the valley of North Fork of Henson Creek are the uppermost. The fossiliferous calcareous shales interbedded with the Burns tuffs indicate a period of quiescence during which animal and plant life existed.

Erosion preceding the Potosi.—Although erosion took place more or less continuously throughout the Silverton volcanic epoch, as is strikingly shown in the Silverton quadrangle and in the regions to the east, its results were obscured by repeated eruptions or outpourings of lava, and it was not until the cessation of volcanic activity of that epoch that the streams began to make headway in the destruction of the volcanic rocks. The greatest work seems to have been accomplished by the streams situated some distance south of the Ouray quadrangle, in the present Rio Grande drainage area. The configuration of the base of the Potosi lavas in the southeastern part of the Ouray quadrangle shows that at the time of their outpouring that region was a rolling country with shallow valleys.

Potosi volcanic eruptions.—The eruptions of the Potosi lavas in the Ouray region were very extensive and were possibly of more varied character than those of which records are preserved in the Telluride and Silverton quadrangles. Lava flows predominated, with minor eruptions of fragmental material, and, although the majority of the lavas were latites, andesites appeared from time to time. From the greater development of the Potosi rocks in the central San Juan Mountains, and the widely distributed outliers, it is plain that the lava floods covered thousands of square miles and that the epoch was of long duration. It remains for studies in the central and eastern San Juan Mountains to determine whether the Potosi was succeeded by still other volcanic epochs capable of distinction.

No information has been obtained which would suggest that the lavas were derived from a restricted volcanic center; on the contrary, their different character and distribution, as well as the presence of basic flows, indicate more than one center of eruption. It is probable that many of the andesite and latite dikes or small crosscutting bodies of the Ouray quadrangle occupy conduits through which some of the later lavas may have reached the surface.

INTRUSIONS.

Probably during the time that the Potosi lavas were being erupted the laccolithic and crosscutting bodies that occur at various places in the quadrangle were intruded. Certain of these bodies cut Potosi lavas and were intruded when a greater thickness of the Potosi rocks existed. They probably belong to the close of the Potosi period.

The laccolithic masses and sheets of Canyon Creek and Uncompahgre River near Ouray may have been intruded at any time after the San Juan epoch, so far as their relations to the inclosing rocks give evidence, but their similarity in composition to the dikes of Porphyry Basin and to the Potosi lavas themselves favors the belief that they belong in general to the Potosi epoch.

POST-POTOSI TILTING AND FAULTING.

At some period later than the eruptions of the volcanic rocks the whole region was affected by slight differential tiltings accompanied by faulting. The tilting was in general to the east and is only vaguely recorded in the Ouray quadrangle by variations in elevation in the Telluride conglomerate. In the Silverton and Telluride quadrangles the inclination of the conglomerate is clearly shown. The faulting, which was very marked in the Silverton region, is restricted to two areas in the Ouray quadrangle in the vicinity of the town of Ouray and near the northern border of the quadrangle. Except the few large faults near Ouray no great displacements occurred, but small fractures were abundant and were closely associated with the formation of the ore deposits of the region, as pointed out in the section on economic geology.

PLEISTOCENE HISTORY.

Erosion.—At the close of the long period of volcanic activity and following slight oscillatory movements accompanied by minor faulting, a cycle of erosion began that is still in progress. The principal drainage systems were early determined and a vast amount of erosion appears to have been accomplished before the beginning of the glacial epoch, developing a topography which did not differ in its broader features from that existing to-day, and many elements of which are still preserved in the region north and west of Ouray. The mountainous area was bordered by a region of very moderate relief occupied by broad, open valleys with low divides between them; active erosion in this lower region had ceased, but it was still in progress in the mountains, where narrower and deeper valleys existed, with sharp ridges between them surmounted at many places by crests of bare rock. Near the northern border of the quadrangle the valley of the Uncompahgre extended from what is now Cimarron Ridge to the region of Horsefly Peak, about 15 miles west of the quadrangle. From the mountains long, low spurs extended northward, separating the waters of Cow Creek, Uncompahgre River, and Dallas Creek, which joined at nearly the same point as now. Remnants of these old valley slopes are shown in the panoramic view of the Uncompahgre and Cow Creek valleys (fig. 10, illustration sheet).

These surfaces may be traced southward into the mountains, where in both the Uncompahgre and Cow Creek valleys benches are preserved high above the present valley bottoms, marking the position and configuration of the old valleys. Cow Creek had an even grade from its source to its junction with the Uncompahgre, the old surface being still practically preserved in the vicinity of American Flat. Between the point where the stream now leaves the shallow basin at its head to plunge into the present canyon and Oban Creek, traces of the old valley slopes are preserved on the crests of spurs between tributary streams, but they are very obscure. North of Oban Creek the gentler outlines of the old valley can be clearly recognized above the present canyon walls to a point north of Lou Creek, where they merge with those of the Uncompahgre.

Similar relations between the older and younger levels may be recognized in the upper portion of the Uncompahgre Valley, although less clearly preserved on account of recent landslides.

Summarized briefly, postvolcanic erosion had developed a mature topography before the advent of the glacial epoch.

Earlier glaciation.—With a change in climatic conditions, the mountains were covered with snow. Snow fields occupied also the higher valleys and from them streams of ice descended to the lower country. The topography did not favor glaciers of great length and on leaving the narrower valleys they deployed and deposited over the lower valleys a mantle of drift which extended well up toward the divides. Some of this drift, especially that still preserved north of Lou Creek, was transported but short distances, probably by névé ice on a valley side rather than by true glaciers. The streams issuing from the ice-filled valleys were greatly increased in volume and carried with them enormous quantities of detritus supplied by the glaciers, which was deposited as outwash gravels or valley trains. Gravel deposits, believed to be of this origin, have been observed far down the Gunnison Valley, and pre-Cambrian quartzites and schists derived from the Needle Mountains have been found near San Juan River, 100 miles from their source on the south side of the mountains.

The only true moraine that has been recognized as belonging to this early stage of glaciation occurs west of the quadrangle at Horsefly Peak. Part of this eminence, as well as of the surrounding hills, consists of Mancos shale, but it is covered with a thick mantle of gravel and bowlders having the hummocked surface of a kettle moraine.

Pleistocene landslides.—Toward the close or immediately after the retreat of the ice, landslides of enormous proportions took place from the abrupt mountain faces which then, as now, extended westward from the Uncompahgre Valley. The débris of these slides was spread far out on the lowland at the foot of the mountains. A remnant of this accumulation is preserved on the present upland west of the Uncompahgre, drained by Coal Creek, and at many other places farther west.

Interglacial erosion.—On the disappearance of the ice the streams entered on a period of very active erosion, during which the canyons of Uncompahgre River and Cow Creek were developed. The reason for this renewal of activity on the part of the streams is not fully understood, but it seems necessary to recognize two elements as taking part in their revival. One of these was doubtless a marked increase in volume of the streams incident to the melting of the ice, but this in itself can not account for such extensive erosion as took place near the head of Cow Creek, resulting in the cutting of a canyon at least 1000 feet below the level of the former valley. The other element and the one which, from our present knowledge, seems to have been the more potent, was an uplift of the whole region, probably of a differential character and following the lines of the post-Laramie doming of the San Juan district. In any event, the streams carved deep canyons near their heads and lower down incised themselves in their old valley floors, developing new and broad flood plains bounded by sharp terraces on which old stream gravels were preserved.

Later glaciation.—After the interval of active erosion glacial conditions again prevailed and of this stage abundant records are preserved. The glaciers extended only to the edge of the lowlands at the foot of the mountains, where the Uncompahgre Glacier deposited a large terminal moraine. The small catchment area at the head of Cow Creek produced only a moderate supply of ice and the glacier in this valley was not large. To judge from the large quantity of drift that occurs in the lower parts of the two western forks of Cimarron Creek, heavily laden glaciers occupied both of these valleys and also that of the main stream to the east. So full was West Fork that a part of the ice flowed over the low divide at the head of Owl Creek and descended some little distance down this stream.

The most conspicuous erosional features resulting from the ice are the cirques at the heads of the main valleys and tributary streams. The development of some of these basins, examples of which can be found in the eastern tributaries of Cow Creek, was undoubtedly begun during the earlier stage of glaciation, but the process continued and the forms were perfected in the later stage. The Amphitheater, east of Ouray, the floor of which beneath its landslide cover lies at about the present level of the Uncompahgre, must owe its very perfect cirque form to the later stage of glaciation, to which also must be attributed the U-shaped modification of the cross section of the valley of Canyon Creek. Between Ouray and the terminus of the glacier lateral morainal deposits occur on the valley sides at elevations gradually decreasing toward the north. The highest point at which such deposits have been observed is at 9500 feet, on the east side of the Uncompahgre just north of Bridalveil Creek, indicating a thickness of about 2000 feet for the ice at this point.

Outwash gravels, contemporaneous with the moraines, were carried far down the valleys beyond the limits of the ice, as in the earlier stage. Such gravels are well preserved in Cow Creek and north of the terminal moraine of the Uncompahgre.

RECENT HISTORY.

Landslides.—Since the final disappearance of the ice, changes of a minor character have been taking place. The most noteworthy events and those which have brought about the most pronounced modifications in the topography were landslides. The topography that resulted from the revival of the streams in interglacial times was of a youthful type, the valleys being deep and their sides precipitous. The effect the ice may have had was further to steepen the valley sides and cirque walls, leaving them, on its retreat, in a more or less unstable condition, depending from place to place on the character of the rocks composing them. In the Silverton folio the landslides of that region were discussed in detail and it was suggested that many of the great rock falls were caused by earthquake shocks. Such an explanation seems entirely reasonable and almost necessary to account for the large number of landslides, the débris of which is to be found in nearly all the higher valleys of the Ouray quadrangle. In Coal Creek and on the west side of the Uncompahgre comparatively recent slips have occurred from the sides of the Pleistocene landslide deposits exposed by interglacial erosion.

Rock streams.—In many of the cirques or basins in the higher mountains occur accumulations of débris resembling ordinary talus in character; these were first described in the Silverton folio and there named rock streams. They consist of rock fragments or blocks, which cover the bottoms of cirques to a depth in many places of 100 feet or more, and extend far out from the bases of the cliffs from which the material was derived, in forms similar to those of small corrie or hillside glaciers. The origin of these rock streams is discussed in detail in the Silverton folio and is here briefly summarized. The deposits are believed to be due to landslides of essentially the same character as those of the lower valleys that have been described, but it has seemed necessary to explain their form and configuration as the result of having fallen upon the surfaces of the basin glaciers or snow fields which were the last to disappear at the close of the glacial epoch. In the Ouray quadrangle they are neither as abundant nor as large as in the Silverton region, though almost the best examples observed occupy basins tributary to Canyon Creek a short distance south of the Ouray boundary.

Postglacial erosion.—A small but definite amount of erosion has been accomplished by the streams since the glacial epoch. This is most clearly shown in the lower parts of Cow Creek and Uncompahgre River, where the outwash gravels of the later stage of glaciation occupy terraces from 25 to 75 feet above the level of the present flood plains. That this erosion is something more than a mere incision of the streams in the outwash-gravel deposits is shown at many points along Cow Creek, where Mancos shale is well exposed beneath a comparatively thin gravel cover. This erosion is comparable to that on a much grander scale which followed the first stage of glaciation, but in this instance it is believed to be largely due to the increased cutting power of the streams resulting from their overloaded condition during the melting of the ice.

Although the larger streams have to-day reached a condition of grade and are depositing broad flood plains in the lower country, the smaller streams are active in the higher mountains and the fans of detritus at the mouths of many of them bear witness to the erosion and transportation of land waste that is still in progress.

ECONOMIC GEOLOGY OF THE QUADRANGLE.

By J. D. Irving and Whitman Cross.

METALLIFEROUS DEPOSITS.

By J. D. Irving.

The metalliferous deposits that have been developed within the limits of the Ouray quadrangle are all in the near vicinity of the town of Ouray and occupy mainly the precipitous country on both sides of Uncompahgre River. No one of the important mines is at a greater distance from Ouray than 3½ miles.

Although these ore deposits include only a few highly productive mines, they form a series of very unusual scientific interest. There is a close relation between the geology of the region described in the foregoing portion of this text and the character of the ore bodies. The striking features of each ore deposit are due in large measure to the lithologic or stratigraphic nature of the rock in which it occurs.

GENERAL FEATURES.

Considered as a whole, the ore deposits of the Ouray quadrangle form the northern extension of a group of metalliferous deposits that is widely developed in the Silverton quadrangle, which adjoins this quadrangle on the south. Although they are thus in a sense closely related to the Silverton deposits, they form a group which possesses marked individual features.

A few of the larger ore bodies are situated in localities where the rocks are much broken and disturbed, and near intrusive dikes and sheets of porphyry, but most of them are found in formations which have been only slightly disturbed. The veins of the Black Girl and Newsboy mines, on the east side of Uncompahgre River, occur in strata so regular and so free from intrusions that their mineralization occasions no little surprise.

CLASSIFICATION.

The ore deposits are difficult to classify on account of the insensible gradations between even the most diverse types. A single deposit may display very different characters in different rocks, so that it will conform to one type of deposit in one part of its course and to another type in another part. For convenience of description the classification below is given. It will serve to bring into the same group the types of ore bodies most readily discussed together.

1. Fissure veins.
2. Replacement deposits in quartzite.
3. Replacement deposits in limestone.

These three main classes of ore bodies owe their existence to the presence of fissures, in general nearly vertical, in the country rock through which the mineralizing waters have circulated. The form of the ore body deposited is dependent on two factors—the amount of open space in the fissures and the kind of rock through which the fissures pass.

Where the fissures have been open the resulting vein exhibits in many deposits a roughly parallel alignment of minerals and little replacement of the wall rock is noticeable. Where, on the other hand, the fissures have been narrow and more or less discontinuous the maximum replacement is to be observed along soluble beds. The narrow fissures are apt to be developed in considerable number and large, flat masses or shoots conformable to the bedding are formed.

Of far more wide-reaching importance is the nature of the rocks in which the fissures occur. Most of the veins pass through an immensely varied series of rocks and many of them can be traced upward from the red beds of the Hermosa formation through greatly differing sedimentary deposits into the andesite breccias of the San Juan, which form the massive gray cap rock of all the higher hills and mountains. The ore bodies vary as widely as the rocks that contain them. Where a fissure penetrates only impervious rocks little replacement occurs and no lateral shoots are developed. Where there are replaceable limestones, or in some places even quartzites capped by impervious shales, lateral enrichments have been developed, many of them of great extent.

The Bachelor mine is an example of the simple fissure in which replacement has operated only in a small degree. No flat ore bodies can be observed in the mine, because the workings have not yet penetrated sufficiently deep to reach beds of limestone. The Newsboy mine is an instance of a vein of twofold character, where a simple fissure in impervious rocks gives rise to large lateral shoots on passing through beds of limestone. The Bright Diamond and Mineral Farm mines are examples of immense flat bodies of ore in which the fissures are so small that many of them are difficult to detect.

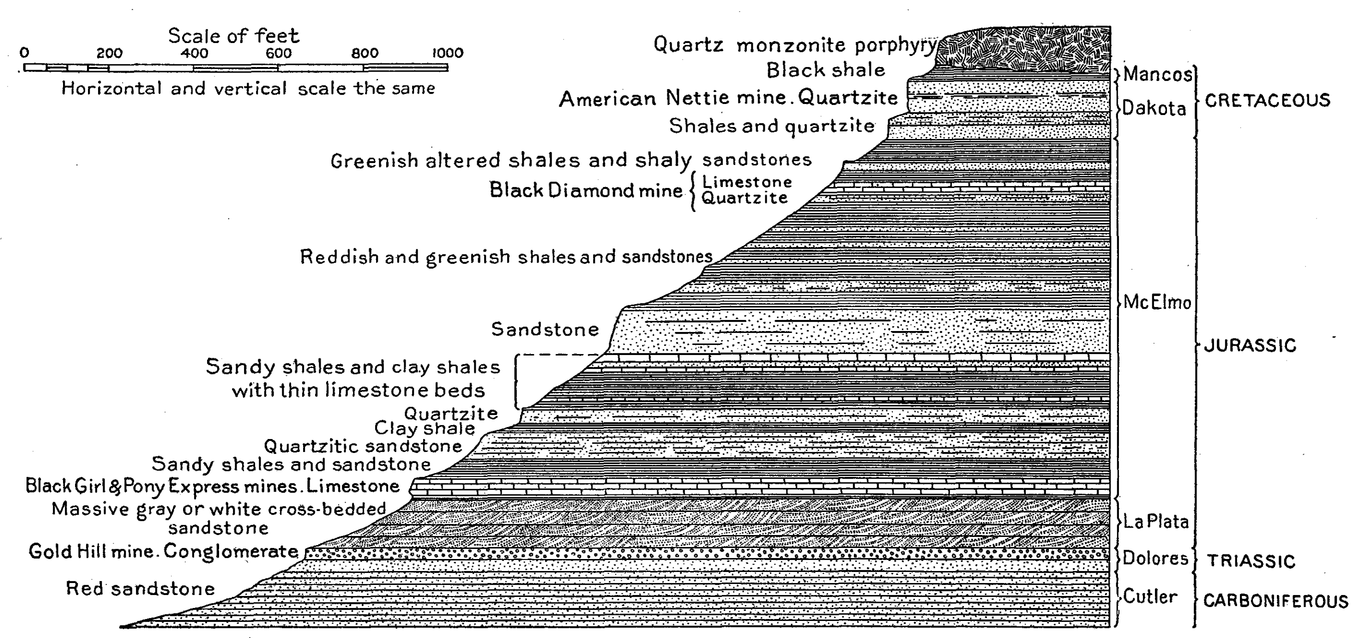


Fig. 1.—Geological section of Gold Hill, 2 miles north of Ouray, Colo.

The accompanying section of Gold Hill (fig. 1), very much generalized on account of the thinness of the beds, will give a somewhat inadequate idea of the varied rocks through which the fissures pass and will also serve to illustrate roughly the horizons in which a lateral extension of the veins most commonly takes place. The influence of the wall rock on the form of the ore deposit can be further understood by reference to the detailed diagrammatic drawings (figs. 2 and 3).

The ore deposits will be briefly considered in the order of the classification already given.

FISSURE VEINS.

SILVER-BEARING VEINS.

LOCATION AND GENERAL FEATURES.

The fissure veins are readily divisible into two distinct groups—silver-bearing veins and gold-bearing veins.

The silver-bearing veins are developed largely along Dexter Creek, where the chief interest has centered about the Bachelor, Wedge, and Calliope mines, and on the east side of the Uncompahgre Valley about 4 miles north of Ouray, the principal mines here being the Newsboy and Black Girl. A few minor developments, as yet only of prospective value, occur on the uplands lying west of the river; among these the Gem and Teller mines are the most important.

The veins are fissures in the country rock filled with high-grade ores of silver and the accompanying gangue minerals. The strike of the fissures is in general fairly uniform, approximating an east-west direction. Thus in the Bachelor and Calliope mines the strike is N. 83° E.; in the Black Girl it is N. 85° E. The dip of the fissures varies from a vertical position to about 60°. Dips of 45° are known, but are rather uncommon. The fissures as a rule show a slight displacement, rarely reaching as much as 7 feet and generally so small as to be distinguishable only by close observation. The width varies from a few inches to as much as 8 feet, a fair average being about 3 feet. Most of the veins are rather uniform, retaining their width for the larger portion of their course without marked variation, although pinches and swells are noticeable in some of the mines.

The country rock in which the veins occur is the varied series of sediments lying below the andesite-breccia cap and comprising the following beds, named from above downward:

Section of country rock containing silver-bearing veins.

1. Mancos black shale.
2. Dakota quartzite and sandstone, alternating with black shale.
3. A highly varied series of clay shales, sandstones, sandy shales, calcareous shales, and limestones, belonging to the McElmo formation of the Jurassic.
4. Red sandstones and conglomerates, with some reddish shales.

These sediments have as a whole a gradual downward inclination in a direction north of east, which eventually brings them down across the bed of Uncompahgre River along its northward course. The dip in undisturbed localities is about 10°. Local disturbances have increased or reversed the dip, as in the Bachelor mine, where the strata dip at an angle of about 10° SE. Steeply inclined beds occur in only a few of the mines. The dip at the Calliope and Iowa Chief mines is about 25° SE., but this inclination holds good for only a small area. In some places the ore is contained within two fairly well defined walls; in others the fissure is divided into branches that separate from and unite with one another repeatedly. Cross fractures further unite the divided branches so that in many places the resulting network passes into a more or less brecciated structure.

RELATION OF FISSURES TO WALL ROCK.

The relation of the ore in the fissures to the wall rock is peculiar. The ore is much more abundant and of very much higher grade where it is included between walls of quartzite, and it is either absent or of a low grade where the fissure passes into shales. In some mines, such as the Iowa Chief, on Dexter Creek, this is due to the narrowness of the vein in the clay shales. It is so narrow as to be in most places a mere fracture in the sediments, with no appreciable open space. On passing into the quartzite, a rock more capable of supporting

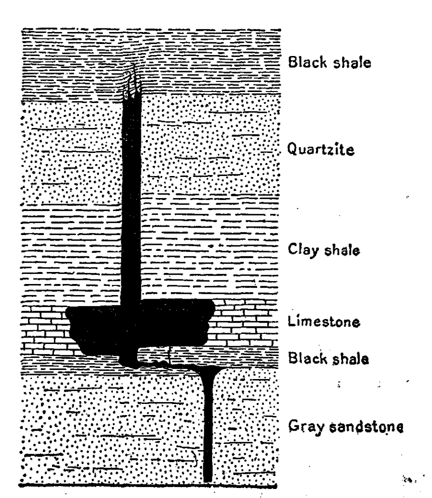


Fig. 2.—Type of silver-bearing vein modified by replacement and bedding fault, Ouray, Colo.

large cavities, the vein widens and rises so much in value as to furnish very considerable profits. In other places, however, the vein suffers no appreciable diminution in size on reaching the shales, but the ore minerals seem to have been deposited only between the layers of quartzite, the portion of the vein in the shales being occupied by barren gangue material and clay.

Again, where the vein passes through limestone, flat shoots of ore are developed, running parallel to the main fissure and many of them extending laterally for distances of 25 to 30 feet or more from the main body. These shoots are formed by replacement of the limestone by ore and gangue minerals and are clearly derived from the main vein. Such replacement bodies constitute a class of deposits so distinct from the fissure veins in their general character that they will be further described under the head of "Replacement deposits in limestone."

The silver veins of the Dexter Creek and Uncompahgre district do not pass upward into the andesite breccia of the San Juan formation. Those in The Amphitheater, on the contrary, do extend upward into the San Juan. The reason for this difference is that a heavy black shale (of the Mancos formation) lies above the ore in the Dexter Creek country, but no such impervious rock is present in The Amphitheater. The veins, being of but slight displacement, seem to have been lost in these shales, particularly at the Bachelor and Wedge mines, where the ore and vein terminate abruptly and bluntly at the shale horizon.

FAULTING BEFORE FILLING.

Many of the fissures have been affected by bedding faults, which invariably follow the shale beds. Such faults have in many places, as in the Black Girl and Newsboy mines, shifted the upper portion of the vein as much as 30 feet away from its downward continuation. This faulting seems to have occurred before mineralization, as the ore is in general unbroken and follows the shales in a thin band between the two separated portions of the fissure.

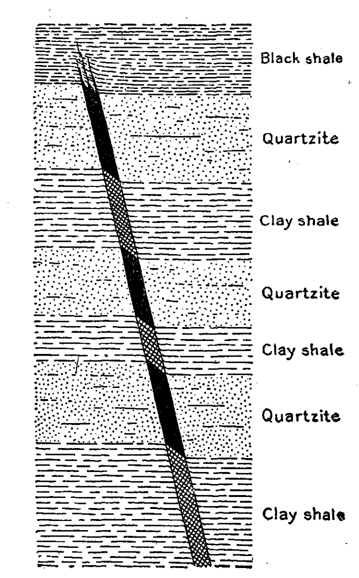


Fig. 3.—Type of silver-bearing vein unmodified.

ORE AND GANGUE MINERALS.

The ore minerals found in these silver veins are of three classes—original sulphides, oxidation products, and secondary sulphide-enrichment minerals.

The original sulphides occur in largest amount in the deeper portions of the mines, but in many places, as in the Bachelor mine, extend upward to the top of the vein beneath the black shales. They consist of argentiferous galena and an antimonial sulphide of copper, locally called gray copper, which carries very high values in silver and is probably related to freibergite. Chalcopyrite and pyrite occur in many veins intermingled with the other sulphides, and sphalerite is present in some of the mines but is generally subordinate in amount. Extensive oxidation has taken place near the surface and much native silver has been developed. Its position shows that it has uniformly been reduced during the process of oxidation. A notable example of such development is afforded by the Calliope mine, where a deep gulch cuts directly across the strike of the vein. The zone that separates the native silver from the unaltered sulphide ore closely parallels the surface slopes, passing down beneath the gulch at a depth slightly less than the distance between it and the tops of the hills on either side. Thus in a profile of the vein the outcrop would show a deep U-shaped depression where intersected by the gulch, and the zone between the two kinds of ore would present the same profile, slightly less accentuated. Similar relations occur also in the Black Girl vein.

Bodies of ruby silver occur here and there in the veins, but are rarely found at great depths below the surface. They are thought to be the result of secondary sulphide enrichment of the gray copper ore, between the zone of oxidation and the zone of unaltered sulphides.

The gangue minerals are quartz, barite, secondary silica, a pinkish carbonate, probably containing magnesium and manganese, and country rock. The secondary silica is as a rule light grayish in color and clearly secondary when examined microscopically. The barite is very abundant and occurs in places in amounts so large as to fill the vein almost completely.

THE BACHELOR MINE.

Among the silver veins the Bachelor vein is of the greatest economic importance, having been the chief silver producer in the district as well as the most productive of the fissure veins. It possesses so many features that can not readily be presented in a general discussion and is in some respects so peculiar that an account of the silver veins would hardly be complete without a detailed description of this mine.[1]

The Bachelor vein has been opened in three places—at the Bachelor tunnel, in Dexter Creek; at the Wedge shaft, on Gold Hill; and in the Neodesha mine, at the base of the cliff in Uncompahgre Canyon. The main openings are those in Dexter Creek. A tunnel here driven southward into the hill intersects the vein at a distance of 720 feet. The country rocks through which the vein passes are sediments of the Mancos, Dakota, and McElmo formations. (See section forming fig. 1.) From the highest level of the mine downward they consist of (1) a series of very fine black shales, in places highly bituminous and containing many thin beds of blackish sandstone; (2) layers of quartzite ranging from 2 to 30 feet in thickness, separated from one another by varying intervals of black and clay shales. The overlying black shales belong to the Mancos, the upper quartzites and the black shale layers in them to the Dakota, and the clay shales and other interbedded rocks to the McElmo formation. The clay shales are mainly greenish in color, in places nearly white, but are so much altered by the action of near-by eruptive rocks that they break with conchoidal fracture into large angular masses. Weathering has locally disintegrated them so that they do not show much difference from ordinary greenish shale unaffected by metamorphism, but in many places they retain their porcelain-like character even after prolonged exposure. The black shales that occur in the upper levels of the mine are repeated at various depths but in thinner layers, and in the lower levels give way entirely to the greenish variety.

Prior to the formation of the ore body the fissures were filled with a peculiar material, now consolidated and locally termed a "dike." It consists of a dense, homogeneous rock containing an immense number of angular fragments of black shale and other country rock in a fine-grained greenish groundmass closely resembling an eruptive rock. This is a friction breccia formed in the fissure. A later opening of the fissure furnished the cavities in which the ore was deposited.

This breccia is as a rule 3 or 4 feet wide but varies greatly in width and in many places makes out in minute stringers into the wall rock, locally showing compact stringers only one-sixteenth of an inch in width that are yet perfectly solid and exhibit all the clastic characters of the wider portions. It is formed so largely of the clayey and aluminous material resulting from the comminution of the shales and limestones which make up the larger part of the McElmo formation that it may originally have had the correct composition for a natural hydraulic cement. The seepage of hot mineralizing waters into the fissure would have supplied the necessary moisture, so that the consolidation was perhaps accomplished more by virtue of the chemical composition of the material than by a high degree of lateral compression as suggested by Ransome[1].

From the Bachelor tunnel the vein has been opened to the east for more than 1000 feet, to the point where it becomes barren, and to the west through the workings of the Wedge and Neodesha mines into Uncompahgre Canyon. At the Wedge shaft, about midway of its course, it divides, both branches passing across Gold Hill and emerging in the cliffs which form the east bank of Uncompahgre River. The two branches are separated by an interval of about 200 feet in this outcrop. The northern branch is worked by the Neodesha mine and the southern presumably by the Pony Express, although no connection has yet been established. The eastern portion of the vein is vertical, as is the portion operated by the Neodesha mine, but the branch that extends into the Pony Express mine is reported to have a slight dip to the south. The trend of the vein east of its division is N. 83° E., or very nearly east and west. In this respect it follows very closely all the other fissures which outcrop in the region about the junction of Uncompahgre River and Dexter Creek.

The fissure, as well as the ore deposited in it, was formed subsequent to the solidification of the breccia or so-called "dike," as it breaks across from one side of the "dike" to the other or is here and there entirely included within it. A faulting by which the south side of the vein has been lowered about 7 feet may be observed along certain portions of the vein. It must have been followed by other lateral movements before the deposition of the ore, as the striations on the harder rocks which form the walls are invariably horizontal. Subsequent to this movement occurred bedding faults which have shifted the upper portion of the breccia to the north. These took place before the vein formation, as there is no evidence that the ore was broken. The ore follows the bedding planes of the strata along the faults, connecting with that in both portions of the dislocated fissure.

The ore occupies mainly what must have been open spaces, as much of it shows parallel banding. It also enters the breccia along cracks and fissures and seems to have replaced this material in some measure.

The ore is a high-grade silver ore carrying from $20 to $75 per ton. Pockets of ruby silver (said to be pyrargyrite) which are reported to have contained 15,000 ounces per ton in silver were discovered shortly after the writer's visit. Gold is either absent or present in very small quantities.

The ore minerals are argentiferous galena and an argentiferous antimonial sulphide of copper locally called gray copper, but probably related closely to freibergite. The copper sulphide is either scattered irregularly through the galena or occurs alone in irregular patches in a pinkish-white carbonate which presumably carries a considerable amount of manganese.

The gangue minerals are quartz, barite, and country rock, angular fragments of which are frequently found in the eastern portion of the mine. The amount of barite in the vein increases from the tunnel westward toward the Wedge mine, where some parts of the vein are no more than a solid tabular mass of massive white barite about 3 feet in width. The manganese-bearing carbonate occurs in small amount, generally associated with the gray copper. It is not a prominent gangue mineral.

The Bachelor mine alone, exclusive of the Wedge, has produced nearly $2,000,000, although unfavorable conditions have materially lowered the profits derived from its exploitation. If the Wedge, Neodesha, and Pony Express were included in the estimate, the total production would be very much greater. Exact figures on these properties have not yet been obtained.

The vein does not outcrop at the surface; owing to the very slight faulting involved in the formation of the fissure it is lost in a mere distortion of the black shales which form its cap. These shales show an irregular twisting in the near neighborhood of the vein, but no fissure is observable and not even the dike itself can be traced upward into them. They have acted essentially as a plastic medium, and even in the often repeated differential movements—the formation of the breccia and the later lateral, vertical, and horizontal movements—they have not been sensibly ruptured. The black-shale fragments in the clastic dike are generally arranged with their flat surfaces parallel to the walls of the vein. They were probably derived in part from the overlying black shale and in part from the numerous black-shale beds just above the La Plata sandstone.

The high-grade ore is shipped to the smelters and gives no trouble other than that involved in a careful sorting. For the treatment of the lean ore a small mill has been erected at the mine. It is fitted with jigs, Bartlett tables, slime-settling tanks, and canvas slime tables. Great difficulty has been experienced here, as in the other silver veins, in saving the silver values contained in the gray copper. This mineral is converted into slime even with the most careful crushing, and floats on the top of the water so that a large part of it is lost. The canvas tables save a little and are a valuable feature of this mill, but even by their aid a considerable loss of silver can not be avoided.

VEINS IN THE AMPHITHEATER.

A group of silver-bearing fissure veins of a very different character is found at the head of The Amphitheater, in the almost inaccessible cliffs that surround the glaciated valley. They exhibit many different strikes and dips and pass from the limestones and shales into the andesite breccia of the San Juan formation.

These veins contain silver and gold in about equal proportions. The silver preponderates in most places, but here and there the reverse is true. The gangue is in the main white quartz and rhodochrosite, or some carbonate intermediate between that and calcite, but in many of the veins the gangue is entirely quartz. The veins vary in width from a few inches to 4 feet and are apt to pinch out within short distances. In the sediments below the andesite breccia they form numerous lateral enrichments in the limestone, but none of those noted were extensive. Ore minerals occur in very small quantities in the gangue. Those observed are galena and gray copper, but stephanite and other rich silver minerals have been reported from these veins. The ore deposits of this district are as yet of merely prospective value.

COMMERCIAL CONSIDERATIONS.

The ore from the silver mines ranges in value from $30 to $800 per ton. Very high values have been obtained from the oxidized portions, where the native silver is in large amount, and the bonanzas of ruby silver occasionally found have also yielded exceptionally high returns. In the majority of the mines, however, values of 60 to 200 ounces per ton may be regarded as the average for shipping ore. The rich ore is usually shipped by rail to smelting centers and there smelted, and where lean ore is encountered, as in the Bachelor mine, the concentrates are shipped in like manner. A local smelter at Ouray was in operation at the time the district was visited, and treated the lower grade material, but it has not yet received from the mine owners the encouragement necessary for profitable operation.

GOLD-BEARING VEINS.

The gold-bearing veins are far subordinate to the silver-bearing veins in economic importance. They are developed along the course of Uncompahgre River between the mouth of Dexter Creek and the town of Ouray, outcropping in the steep cliffs on either side of the canyon. The country rocks which form these cliffs are, from below upward, the red sandstones, conglomerates, and sandy shales of the Hermosa and Cutler formations (Carboniferous); the red shales and sandstones of the Dolores formation (Triassic), lying unconformably above at a slightly different angle; the white and gray sandstone of the La Plata (Jurassic); the alternating shales, sandstones, and limestones of the McElmo (Jurassic); and the Dakota sandstone and black Mancos shale (Cretaceous). The inner and steeper walls of the canyon are formed of rocks of the lower part of this column—that is, the red beds below the La Plata sandstone.

Numerous dikes and irregular intrusions of quartz-bearing monzonite porphyry cut diagonally across the sedimentary rocks, some of them vertical, others with a marked dip toward the south. On the west side of the river irregular sheets extend outward from these dikes and pass between the sedimentary beds. The small dikes weather so much more readily than the sandstones that they can be found only at the bottom of deep clefts in the cliffs, but many of the larger dikes lie nearly flush with the canyon walls. The veins occur either wholly within the dikes or closely associated with them. They comprise a group of highly inclined sheeted zones, made up of a series of irregular and closely spaced fissures, mostly of small throw and in many places aggregating 5 or 6 feet in width. The ore consists of gold-bearing pyrite and chalcopyrite in a gangue of country rock and clay, the clay having been derived partly from intercalated shale beds and partly from porphyry. The filling of open spaces seems to have been subordinate to the replacement of the wall rock, which has occurred to a considerable extent. The ore lies in small shoots in the vein and is so irregular in its distribution that the veins are mined with some difficulty.

The veins are later than the porphyry, as they can be seen distinctly faulting that rock. Both the dikes and the associated veins strike about N. 83° E., parallel to the majority of silver-bearing fissures. The dip is in some places vertical, in others as low as 50°.

Nearly all the mine workings are situated high above the bottom of the canyon, in the steep faces of the cliffs, and the ore was brought down by means of wire-rope tramways, all of antiquated model and now in disuse. Owing to their prominent position these mines were among the first to be operated in the district. They are now either idle or operated under lease. They were never very productive or profitable, presumably because the irregularity of the veins and their small size rendered their working uncertain, and the methods of treatment were not adapted to the ore.

The values are largely in gold, although a little silver is generally present. Exact and reliable data are difficult to obtain, but the gold values, where present, are undoubtedly high. The average yield is probably between 2 and 3 ounces of gold per ton, making a high-grade ore of $50. In some mines, as the Grand View, a little of the ore runs up to 8 ounces, and as much as 30 ounces has been reported.

REPLACEMENT DEPOSITS IN QUARTZITE.

CHARACTER AND GENESIS.

The ore deposits that have been grouped under this heading contain gold with very subordinate silver and occur in irregular bodies in strata of massive quartzite. They are termed "replacement ores" because they have been formed, not by the filling of open spaces existing previous to their deposition, but by a chemical interchange of ore material for original country rock. The mineralizing waters by which they were produced have been both the solvents of the country rock and the agents which have effected the ore deposition. In some places the solvent action of these waters has been greater than their depositing action, so that cavities exactly similar to solution caves in limestone have been produced, and yet no ore has been deposited.

COUNTRY ROCKS.

These ores are found in a number of the Mesozoic quartzites—altered sandstones—which outcrop on both sides of the Uncompahgre Canyon. The uppermost of these rocks, in which the majority of ore bodies have been found, is the highly indurated Dakota sandstone of the Cretaceous, which will be referred to as a quartzite. The others lie at varying intervals below this rock, and constitute a portion of the McElmo formation of the Jurassic, but there are many similar beds and they vary so much from place to place that they can not be correlated with one another. It is a prevailing impression in the district that there are two ore-bearing quartzites, an "upper" and a "lower," which are readily traceable for great distances. This impression is founded on error. The Dakota quartzite alone is a prominent and constant stratum. Below this are many other quartzite beds, and of the ore bodies in them it can not be proved that any two occur in the same bed. This may readily be understood from the geological section (fig. 1), although even here it has not been possible to represent all the thinner quartzite beds.

The Dakota quartzite is a dense white rock varying from 25 to 100 feet in thickness and containing intercalated beds of shale, mainly at the center, but not constant in either position or amount. In the upper portions it is finer grained, the bedding planes are closer together, fine shaly

[1] For a previously published description by Dr. F. L. Ransome see Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 227-236.

partings are observable, and it is slightly blackish, owing to included carbonaceous material. Above it is a series of black shales that are extremely thin bedded and so highly charged with coaly matter as to resemble strongly the shales commonly associated with coal. The Dakota is underlain by the greenish shales of the McElmo, and owing to the comparative ease with which these shales are disintegrated and worn away it forms in most places an abrupt cliff. It outcrops on either side of the Uncompahgre Canyon about 2000 feet above the bottom of the valley and follows the indentations made by the steep gulches on either side.

DISTRIBUTION.

The ores are widely distributed along the outcrop of the formation. Among the mines and prospects are the American Nettie, Valley View, Ceutar, Rock of Ages, Samoa, and Stenographer. In form, mode of occurrence, and contained values all these deposits are similar, differing only in unimportant details. In but one mine, however, the American Nettie, have the ore bodies yet proved sufficiently extensive to be of commercial value. The general description of this class of ores will therefore best be accomplished by a description of this mine.

AMERICAN NETTIE MINE.

The openings of the American Nettie mine are located near the lower portion of the steep cliff which forms the top of the canyon wall on the east side of the Uncompahgre, 1800 feet above the bottom of the valley. The buildings that have been

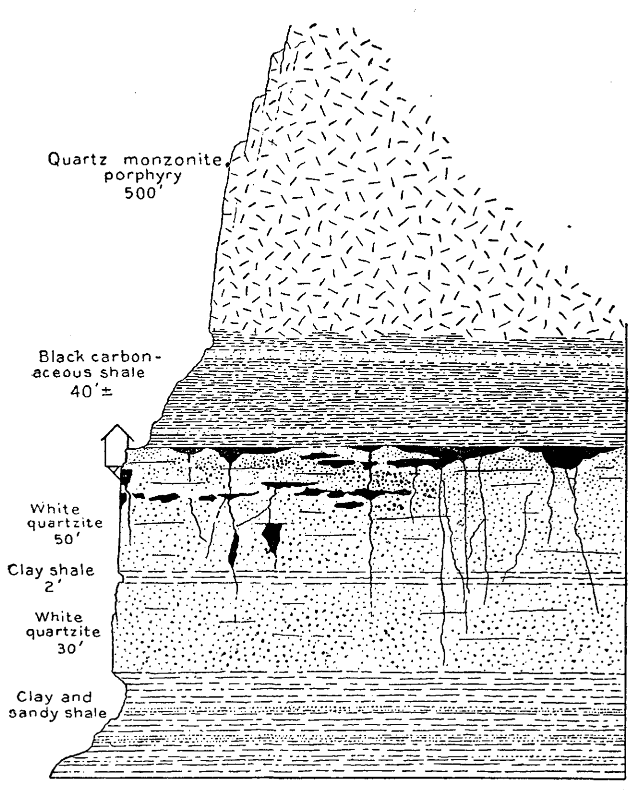


FIG. 4.—East-west section of the rocks and ore bodies in the American Nettie mine, Ouray, Colo.

erected near the entrance are about 100 feet above the base of the perpendicular bluff, and so little support does the rock face afford that they are kept in place partly by wooden brackets, and except for their modern construction might well pass for cliff dwellings. The position occupied by the country rocks may most readily be understood from the little sketch forming fig. 4. Above the mine is an immense sheet of quartz monzonite porphyry aggregating about 500 feet in thickness, underlain by 40 to 50 feet of fine black shales, very heavily charged with carbonaceous matter and containing a few thin beds of black sandstone. Conformably below these shales is the ore-bearing quartzite, a massive white rock, fine grained and blackish at the top and coarser grained and white below. It is separated into two portions somewhat below the middle by a thin parting of light-colored shales. Below this quartzite lie the variegated shaly rocks of the McElmo formation. These beds dip into the hill at a low angle, from 5° to 10°, slightly to the east of north. Locally, however, the dip is much steeper. All the rocks are cut by a number of dikes of dark-colored fine-grained porphyry, probably connected with the monzonite sill above; some of the ore is found beside them, but the larger part is widely separated.

A heavy fault fissure filled with a consolidated breccia similar to that observed in the Bachelor mine runs eastward and is followed by the main tunnel of the mine. Locally it is simply a fault fissure with no filling material in it. The breccia is termed a "dike," but is not correctly so considered. It is the impression of the miners that the ore emanates from this fault breccia and makes out from it into the country rock, but an examination of the mine and a glance at the mine map, as well as a comparison with a large number of precisely similar occurrences in quartzite, where no fault breccia and no porphyry dikes are present, show that there is no connection between the two.

The quartzite is seamed by irregular branching fissures, in general nearly vertical in position, some of them extremely narrow and others as much as 2 or even 6 inches in width. The displacement along the fissures is very slight, the maximum observed being 10 inches. They are filled with white crystalline quartz and almost invariably show a perfect comb structure. The wider portions show open vugs lined with quartz crystals. The fissures intersect one another in two prevailing directions, though many local variations and irregularities occur. Most of them pass upward into the shales, where they are generally lost, but those on Cascade Creek pass into the porphyry sheet, which rests directly upon the quartzite. They are therefore later than the porphyry. A few of the fissures are wide enough to be termed "fissure veins," and carry ore minerals in sufficient quantity to be mined as such, but these are uncommon.

Along the course of the fissures ore bodies or shoots extend outward for as much as 20 feet. The most typical of these shoots are irregular bodies, ranging from a few inches to 15 feet in thickness, longer in the direction of the fissure than across it, and with their larger dimensions in a horizontal position. Many of them are exceedingly irregular, wandering through the quartzite in all directions, but generally they are concentrated along a definite bed, as a rule just under a fine shale band, which is locally so thin that it can be detected only where the rock is broken parallel to it. In the vicinity of the supplying fissures some of the shoots are pear shaped, with their longer axes parallel to the planes of stratification of the quartzite, the ore solutions having seemingly passed laterally along the bedding. The largest shoots lie immediately beneath the black shale at the top of the quartzite. In places several tiers of shoots occur along a single fissure.

The ore in these masses is located chiefly near the supplying fissures, where it forms a solid mass, but outward along the strata it only partially fills open cavities, merely lining the interior in many of them. On the extreme outer limit of the shoots only empty cavities lined with quartz crystals are to be seen. These contain no ore whatever, and many of them extend for 30 feet beyond the ore shoot. It is a saying among the miners that as soon as one finds crystals in the quartzite there will be no more ore. These empty cavities have all the characteristics of cavities produced by solution in limestone and can in no wise be distinguished from them except for the lithologic character of the containing rock. There can be no question that they were produced by solution.

The ore was first discovered on the face of the quartzite cliff and occurred in irregular open cavities, which were exposed by the breaking away of the outer portions of the rock. Here, and for a long distance into the side of the hill, it consisted of a brownish, iron-stained material resembling limonite and containing free gold, either too fine for observation or in the form of wire gold. It did not entirely fill the cavities, but was concentrated in their lower portions. The gold was crystalline and was almost invariably richer at the bottom of the mass. The present foreman reports only wire gold, but it is stated that large nuggets were found, some of them of great size. The brown material is undoubtedly limonite in great part, but in all probability further examination will show that it contains a large percentage of ferric sulphate. Mixed with the oxidized ore are siderite, barite, kaolin, and sulphur.

In many cavities honeycombed quartz is observable, as much as 4 or 5 inches in thickness, either lining the cavity or completely filling it. Some of the cell-like spaces in this quartz are irregular, but many have the form of pyrite crystals, showing clearly that they are caused by the oxidation and removal of former masses and crystals of iron sulphide. Formerly much of the oxidized ore was shoveled directly from the cavities into ore sacks and shipped, but careful sorting is now necessary.

On penetrating farther into the hill the ore gradually changes to pyrite. This mineral is either massive, with cavities here and there into which complete crystals of pyrite project, or is composed of crystalline grains of pyrite embedded in a matrix of gray and white secondary quartz. Large admixtures of chalcopyrite and galena with other sulphides are found, among which are sphalerite, telluride of gold and silver (perhaps hessite, found most extensively on the Jonathan claim), molybdenite, and gray copper (probably argentiferous tetrahedrite). Barite is also of very abundant occurrence in the sulphide ore, and fibrous bands of gypsum were seen between the ore and the overlying black shales. The sulphide ore is more common directly beneath the black shales, as are also the more extensive ore bodies.

The contact between the ore and the quartzite is in most places very sharp and shows the irregular and undulating surface so often seen in replacement deposits.

The value of the ores is almost entirely in gold. Silver is subordinate, although as much as 120 ounces is found in some places, especially where gray copper and galena occur mingled with pyrite. The gold values are unusually high, some of the ore yielding as much as 30 ounces. At the time the mine was visited the ore would average when sorted about $60 per ton. Owing to high freight and smelter charges $35 per ton is considered the lower limit for sulphides. In the early days of mining the values were uniformly higher than at present.

Between 1889 and January, 1905, the mine produced 23,641,316 pounds of ore, valued at $1,464,923.35. This would give an average value of $123.12 per ton, or, roughly, 6 ounces of gold per ton of sorted rock. This agrees very closely with the average values obtained from the Bright Diamond quartzite ores and the most important of the other similar though smaller deposits found along the outcrop of the Dakota quartzite.

Much of the ore is shipped direct. It is transported by a wire-rope tramway from the mouth of the mine across the Uncompahgre Canyon to the ore bins along the side of the railroad. A mill adjoining the ore bins has been used to concentrate the leaner sulphides. It is not in operation at the present time. The tramway is a striking feature of the mine. It has a total length of 4100 feet and a span across the canyon of 1800 feet. The highest point of this span is 900 feet above the bottom of the valley.

OTHER MINES.

Except in point of production the other deposits in quartzite closely resemble those of the American Nettie mine. From a lower quartzite in the Bright Diamond mine high-grade ore to the value of $32,000 was obtained from small shoots. It is probable that further exploration may reveal other important bodies of ore similar to those of the American Nettie.

REPLACEMENT DEPOSITS IN LIMESTONE.

A series of broad, flat ore bodies are found in beds of limestone either adjoining fissure veins or associated with numerous small vertical or nearly vertical fissures that intersect the stratified rocks. These deposits have been formed by the removal of limestone and the simultaneous substitution of ore minerals for it by mineralizing waters, which here gained access to the more soluble rock by means of the fissures. They are more regular than the replacements of quartzite just described, and much more extensive, a few of them being fully 300 feet wide. Gold predominates in some of them, silver in others, but the ores which they furnish are uniformly of lower grade than those in quartzite. The silver-bearing deposits are associated with the silver-bearing fissure veins already described, and are found only where these veins penetrate strata of soluble limestone.

These replacement deposits may be most conveniently classified according to the prevailing gangue minerals present, as baritic siliceous ores (silver bearing) and magnetite-pyrite ores (gold bearing). All the ores of both groups differ a good deal from one another, so that collective description will give only a most general idea of their character.

BARITIC SILICEOUS ORES.

The baritic siliceous ores are lateral enrichments of silver veins or flat masses associated with small vertical fissures. The most important are in the Newsboy, the Pony Express, and the Mineral Farm mines. In the Newsboy and Pony Express a fissure elsewhere productive as a vein is connected with the deposits; in the Mineral Farm no important vertical fissure veins are found, and it is only by close observation that the knife-edge fissures may be noticed.

At the Newsboy mine the limestone which carries the ore is bluish black in color, and is overlain by clay shale and sandstone and underlain by thin-bedded black shales and a heavy gray sandstone. It is about 5 to 7 feet in total thickness. The shoots of ore here are flat masses and as a rule fill the entire space between roof and floor. Laterally the valuable portions of the ore material extend from 5 to 30 feet from the fissure, although the silicification goes much farther. The shoots run nearly east and west, parallel to the direction of the fissure, for distances of 300 feet or more in places. Most of the shoots lie north of the vein. The ore-bearing limestone bed is at the base of the McElmo formation, immediately above the La Plata sandstone. Its position may be seen in the Gold Hill section shown in fig. 1.

The same limestone bed extends along the canyon to the Pony Express mine, where it is about 30 feet in thickness, and is overlain by shales. The shoots in this mine are much larger and thicker than usual. They extend into the hill for 1000 feet along the course of the vein, and are in many places 100 feet wide. The stopes now form great chambers, separated by irregular pillars of limestone or ore, and are very suggestive of a coal mine. The ore in places occupies the entire 30 feet of rock, but is more commonly 8 to 10 feet thick. It is richer immediately beneath the shale roof, but is not everywhere in contact with it. The limestone where unmineralized is much brecciated and full of cavities, which have probably been more important in determining the mineralization of the rock than the overlying shales. In the Mineral Farm mine the limestone belongs to the Ouray formation. The ore shoots are here from 8 to 10 feet thick and 6 to 50 feet wide. The workings follow one shoot for a distance of perhaps 600 feet. This shoot has a strike of N. 63° E. The narrow fissures with which the ores are associated may be seen at many places in the roof of the ore, but are not noticeable without careful examination.

The ores of the limestone replacement bodies are bluish gray or buff, according to the color of the original limestone. They consist of fine-grained silica heavily charged with crystalline barite and containing argentiferous gray copper (freibergite), galena, and in some places chalcopyrite. The metallic minerals are either disseminated in small grains through the silica and barite—especially the gray copper—or concentrated in bunches of irregular form and character that are distributed at uncertain intervals through the siliceous gangue rock.

Irregular cavities lined with druses of quartz crystals form a prominent feature of the ore. In the unoxidized portions silver chloride and secondary black copper sulphide can be observed at many places. The silica extends to great distances beyond the metallic replacements and continues locally for the entire visible outcrop of the limestone bed. In the Pony Express mine, however, the siliceous replacement is slight, and the gangue of the ore consists to a great extent of immense masses of barite in otherwise unaltered limestone.

In the massive sulphide bodies the gray copper can be readily seen, but in the usual run of ore it is apt to be disseminated through the gangue in grains so small as to be hardly perceptible to the eye.

The larger structures of the country rock, such as brecciation, bedding planes, layers of shale, etc., extend uninterruptedly into the ore, except where, as in the bodies of sulphides, the mineralization has obliterated them.

The values are mainly in silver. The gold content rises in a little of the ore to $4 or $5 per ton, but is generally so low as to be negligible. In the largest masses, such as those in the Pony Express and Mineral Farm mines, the values in the ore are extremely irregular and uniformly low. The ore from the Pony Express is reported to average as a whole about $30 per ton, although much higher values are encountered. In the Mineral Farm mine the average is so low and the richer portions of the ore are so irregularly distributed that the deposit has never yet paid for exploitation. In the Newsboy the values are uniformly higher, and many carload lots will carry as much as 100 ounces of silver. It is difficult to form a correct estimate of the production of this class of ores, as they have generally been worked intermittently under lease.

MAGNETITE-PYRITE ORES.

The magnetite-pyrite ores are of greater scientific than commercial interest. They have been found at only one locality—in the Bright Diamond and Iron Clad mines, on the east wall of the Uncompahgre Canyon, about 600 feet below the American Nettie mine. The ore occurs in a fine-grained dark-blue limestone, apparently quite pure and, where unmineralized, without any evidence of alteration. This stratum is about 10 or 15 feet thick and is overlain by green shale that has been altered by the monzonite-porphyry intrusions into a green porcelain-like argillite heavily charged with epidote and other metamorphic minerals, and of an exceedingly dense, impervious character. The ore occurs in broad, flat shoots, conformable to the stratification and having a uniform thickness of about 6 feet. It lies in close contact with the shale roof. The strata are nearly horizontal, but show local dips, and are intersected by a series of widely spaced fractures which run in a nearly east-west direction and fault the strata in many places as much as 10 feet, with downthrows here to the north and there to the south. The ore outcrops for a long distance in the cliff near the mines. In the Bright Diamond mine a porphyry dike 10 to 30 feet in width occurs north of the ore, and the heavy monzonite-porphyry sheet above the American Nettie mine lies about 700 feet higher. The ore is not in contact with the dike, but is some distance south of it.

All the rocks except the unmineralized portions of the blue limestones have been profoundly altered by the intrusions, so that they are now very porcelain-like in their character. The shoots where explored are about 300 feet wide, and have been followed into the hill in one place for 400 feet. Wherever the workings leave the ore they pass into unaltered blue limestone singularly free from the contact metamorphism that has altered the more argillaceous rocks of the series.

The ore lies in close contact with the shale roof. It is an intimate mixture of a dense, granular magnetite and pyrite, with a little chalcopyrite, interwoven in the most complicated manner with epidote, actinolite, garnet, quartz, and calcite. In the Bright Diamond mine a large fault-fissure vein lies on the north side of the ore, between it and the monzonite-porphyry dike, and it was in the prospecting work on this fissure that the ores were first discovered.

The ore carries $10 to $14 in gold and is of nearly uniform value, but is concentrated with difficulty and has not yet proved profitable. It is not improbable that magnetic separation may be of material assistance in its exploitation.

GEOLOGIC AGE OF THE ORE DEPOSITS.

Wherever the geologic age of the ore deposits can be ascertained with measurable accuracy the evidence points to a single period of mineralization for all the deposits discussed. They are of very recent formation; all of them are later than the latest of the igneous rocks, as many of the fractures in which they have been formed extend into the eruptives and some of the veins lie wholly within the dikes. These eruptive rocks were formed later than the andesites of the San Juan formation, as in many places they cut the andesite and spread out beneath it in the form of horizontal sills. The eruptives are therefore later than the andesite breccia, which is of Eocene age. We can then conclude that the ore was formed at the close of or later than the Eocene epoch.

SUPPOSED GOLD-BEARING CONGLOMERATES.

Underlying the San Juan andesite breccia, which forms the cap rock of the hills in the Ouray quadrangle, and rests unconformably upon the stratified rocks below, is a formation known as the Telluride conglomerate. This is not everywhere present, but occurs in large development in the vicinity of Cobbs Gulch and Cow Creek. It has been prospected for gold, and an experimental stamp mill has been erected near the mouth of Cobbs Gulch to test its value. The possible occurrence of placer gold in this rock forms a problem of unusual scientific interest on account of its bearing on the geologic period during which the ore deposits of the region were formed.

If the conglomerates carry placer gold, there must have been ore bodies containing free gold in existence before their deposition. It can be proved that the known ore bodies were formed at or later than the close of the Eocene epoch. The conglomerates, however, were formed in the early Eocene and were clearly in existence before any of the known gold ores were deposited. The source of the placer gold therefore—in case it is proved to be present—must be sought in deposits belonging to an earlier geologic period—deposits of whose existence there is as yet no evidence.

Gold may, of course, have been deposited in these gravels long after they were consolidated into rock, but in that case the character of the gold present would show clearly that it was not deposited by placer action.

With these facts in view it seemed necessary to determine two points—(1) whether the gravels contain appreciable quantities of gold; (2) the physical condition of the gold, if present. For this purpose a series of nine carefully selected samples were taken from portions of the rock most favorable for the occurrence of gold, and from widely separated localities. Some samples were collected from places recommended as especially rich; others at points where no prospecting had been done. The samples were very carefully assayed and four of them panned, the concentrates being tested microscopically. The results showed a uniform gold content of 0.005 ounce, or 10 cents, per ton, the panning tests giving small grains of magnetite sand, but no colors.

While these determinations are by no means the result of an exhaustive sampling, they clearly show that if gold is present in this rock in appreciable quantities it must be contained in those portions of the deposit from which no samples were taken. A content of 10 cents per ton in gold is so small that it can hardly be determined even by the most careful methods of assay, and since almost any rock in a mineralized region in the neighborhood of ore deposits may contain values equaling or slightly in excess of this amount, the inference seems justifiable that no gold-bearing lodes existed prior to the deposition of the conglomerate. The purely negative results shown by these samples seem also to afford to those interested in mining in this region a strong reason for the exercise of extreme caution in the exploitation of these Eocene gravels.

MISCELLANEOUS MINERAL RESOURCES.

By Whitman Cross.

COAL.

Coal occurs within the Ouray quadrangle in the Dakota and Mesaverde formations and has been developed to some extent at both horizons.

In the Dakota formation.—Coal is present commonly within one or both of the zones of carbonaceous shale characterizing the Dakota formation, as described on page 6. These zones occur near the middle and top of the formation, and the coal, which is a striking feature of many outcrops, has been opened and worked to some extent at several localities, especially in the northwestern part of the quadrangle, where it is easily accessible. This Dakota coal is subbituminous in character and few or none of the beds are more than 1 foot thick. It has never been mined except for local use and lost even its limited importance with the introduction of better coal from other formations on the advent of the railroad.

In the Mesaverde formation.—Coal measures much more important than those of the Dakota occur in the Mesaverde formation at the head of Lou Creek, on the western slope of Cimarron Ridge. The coal has been opened by short tunnels at the only two points where outcrops are distinct. The locations of these openings and the roads leading to them are shown on the maps of this folio.

Landslide débris and glacial gravels conceal not only the coal but other strata of the Mesaverde formation so extensively that but few outcrops are to be found. At and near the tunnel on Middle Fork of Lou Creek there is almost nothing to be seen of the strata above or below the coal. This tunnel exposes coal to a thickness of 15 feet or more, the base not being seen, and at about 30 feet from its mouth reveals the shaly roof, which has a strike of N. 78° W. and a dip of 25° NW. The structure thus indicated is probably that prevailing in this vicinity, though perhaps with considerable variation in both strike and dip. If the northwesterly dip is prevalent, it is probable that the other coal opening, situated a mile to the southeast and about 300 feet higher than that first mentioned, is in the same coal bed. At this latter point the workings have caved in, but it is clear that the coal bed is comparable to that of Middle Fork of Lou Creek in thickness, and is of the same general character. Blocks of creamy-yellow, friable sandstone are found about this opening, but no distinct outcrops occur.

To the north from the coal banks of Lou Creek scanty evidence was found showing that the measures descend with gentle dip, and on Deer Creek, about 1 mile north of the Ouray quadrangle line, are two openings. The lower of these is at an elevation of about 8950 feet, and is presumably in the same coal bed shown on Lou Creek, or in an adjacent one. The workings are caved in, but it may be seen that the coal is about 15 feet thick and that massive but crumbling saccharoidal sandstones occur, both above and below, within a few feet, the details of the section being obscured. The lower sandstone has a northeasterly dip of 3° to 5°.

Not far from the above-mentioned opening is another, at an elevation of about 9400 feet. A tunnel has been driven into the coal, but neither top nor bottom is exposed. Fragments of a buff sandstone with indistinct plant remains are scattered on the surface near the tunnel but gravel conceals the details of the section. So completely is the coal-bearing formation covered by superficial materials that it can not be determined whether these two openings on Deer Creek belong to the same horizon or not. If they do there must be a fault of several hundred feet between them.

Coal is mined at the upper tunnel for local use of ranchmen. It is reported to have been tested for steam-producing purposes at Ouray, but found to be less satisfactory than the coal of the market. No tests fully determining the character of these coals have been made.

The Mesaverde strata of the Ouray quadrangle are at the southern extremity of an isolated area of this formation which extends northward along Cimarron Ridge for about 12 miles, with a width of 3 to 5 miles. The edges of the nearly horizontal strata are exposed at few places in this district, the landslide and talus débris from the overlying San Juan beds or uppermost Mesaverde sandstone concealing them effectually. The coal has been opened at the north end of the field, a few miles from the Denver and Rio Grande Railroad, but either the character of the coal or other controlling conditions have prevented important development.

BUILDING STONE.

There is no lack of fairly good building stone in the Ouray quadrangle, but the local demand is naturally small and the abundance of good stone in the field which might afford a market has discouraged the development of quarries for export. Some of the light-red sandstones of the Hermosa formation have been used at Ouray. The darker red sandstones of the Cutler and the gray rock of the La Plata might be easily obtained from accessible outcrops.

LIMESTONE.

Inexhaustible supplies of limestone for all purposes are furnished in the Ouray and Hermosa formations, adjacent to the railroad, and they have been used to some extent for lime and as a flux in smelting.

WATER RESOURCES.

As in all districts in the border zone between mountains and a semiarid plateau country, the water resources of the Ouray quadrangle are of much importance. The heavy snow and rainfall of the mountains within or adjacent to the area feed several perennial streams, which are used for irrigation and development of water power. But the chief value of these waters is not for uses within the quadrangle, but rather for the irrigation of the lowlands of the Uncompahgre and Cimarron valleys to the north.

Irrigation.—The irrigable lands of the Ouray quadrangle comprise chiefly the flood plains of Uncompahgre River and Cow Creek and the gravel benches adjacent to those streams. By far the largest area is the bottom land of the Uncompahgre Valley, extending from Portland to Ridgway, a distance of 6 miles, and having an average width of 1 mile. This land is practically all under irrigation by water taken from the river and several tributary streams, the principal ditches being shown on the topographic sheet. Narrow bands of bottom land along the Uncompahgre below Ridgway and on Cow Creek are also cultivated.

Next in importance to the alluvial lands are the lower gravel benches bordering Cow Creek and the Uncompahgre below Dallas, the extent of which may be seen from the geological map. The soils of these benches are perhaps in part eolian, but are largely derived from the low alluvial fans of the side streams. The principal ranch lands of this origin are on the east side of Cow Creek and they are mainly irrigated by the waters of Owl, Nate, Lou, and Deer creeks. Some water for these benches is also obtained from West Fork of Cimarron Creek by a ditch crossing the low divide north of Chimney Peak and discharging into Owl Creek.

Between the Uncompahgre and Cow Creek, in the basins of the intermittent Dry and Alkali creeks, there is some land cultivated by the aid of water from Cow Creek. The soil is here largely adobe, derived from the underlying Mancos shale, and several ranches of this area have been abandoned.

Small patches of arable land are under cultivation at higher levels than those mentioned, adjacent to Coal Creek and other minor streams. No attempt has been made to cultivate the meadows of Cimarron Creek within this quadrangle, the elevation being too great. The water of Cimarron Creek reaches Gunnison River above the tunnel now under construction for the diversion of the river into the lower Uncompahgre Valley.

The crops of the Ouray ranches are principally hay, largely used for the winter feed of cattle, with some grain, potatoes, and other vegetables for the local market. The range of products is limited by the shortness of the season, due to the altitude, the lowest point on the Uncompahgre within the quadrangle having an elevation of 6700+ feet.

Underground waters.—The abundance of surface water and the small area of arable land have made it unnecessary to develop the underground-water resources of this district. There is probably a considerable underflow in the Uncompahgre Valley, but it is not needed under existing conditions. No great flow of this character can be present elsewhere unless it is in the Cimarron Valley.

It may be seen by a glance at the geological map that the area within which all possible water-bearing strata outcrop is very small, and that the outcrops are not far above the valley, hence the supply of artesian water is probably inconsiderable and under low pressure. Furthermore, the fault crossing the Uncompahgre between Dallas and Ridgway must interrupt the circulation of water derived from the mountains. These facts make it probable that artesian wells of much importance can not be secured for the ranch lands of the Ouray quadrangle.

Thermal springs.—Several thermal springs occur within the Ouray quadrangle. One of these issues from the lower part of the Hermosa formation, on the eastern border of the town of Ouray, and is used in two bath houses. According to the proprietor of this spring, Mr. John McLeod, the water has a temperature of 125° F., and fills a 3½-inch pipe, with a pressure of 25 pounds to the square inch. No analysis of this spring water has been made.

Analysis of water from hot spring at Ouray.

	Grams per liter.
SiO_2	0.3760
SO_3	.6263
Cl	.0361
CO_2	.0323
CaO	.4966
MgO	.0173
Na_2O	.0979
FeO	.0202
	1.7027

Total residue on evaporation 1.880 grams.

Other springs within the town limits issue from the Ouray limestone near the fault line which crosses both Canyon Creek and Uncompahgre River, a short distance above their junction. One of these, situated on the river about 50 feet above the mouth of the creek, has a temperature of 68° C. According to Mr. G. E. Kedzie an analysis of the water of this spring yielded the result shown in the foregoing table.

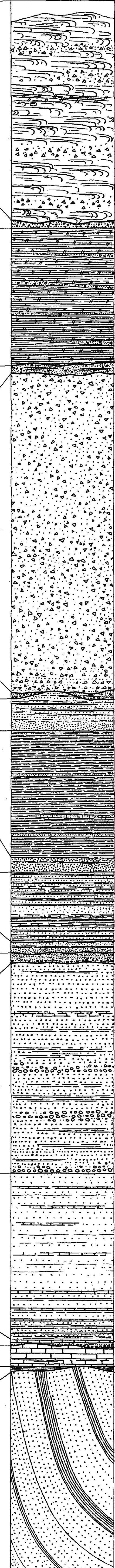
Another spring, or group of springs, occurs on the eastern side of the alluvial flat of Uncompahgre Park about 2 miles southeast of Ridgway. The water is heavily charged with iron and there has been deposited from it a thin sheet of red ferruginous tufa covering several acres. According to the owner, Mr. L. F. Orvis, jr., the water has a temperature of about 110° F. It issues under slight pressure and the discharge is sufficient to irrigate 15 acres of land. No analysis has been made. The water presumably comes from the red strata of the Cutler formation, from which it no doubt derives its iron content. Peale refers to these springs in the Hayden Survey report for 1875 as follows: "A short distance above the mouth of Dallas Fork are the springs which give the name of Uncompahgre—red-water spring—to the river and park."

June, 1906.

COLUMNAR SECTION

GENERALIZED SECTION FOR THE OURAY QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.



System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
TERTIARY	Potosi volcanic series.	Tp		2000	An alternation of rhyolite, quartz latite, and pyroxene andesite flows and tuffs, the flows greatly predominating. Some of the thin flows in Whitehouse Mountain are glassy.
	UNCONFORMITY				
TERTIARY (Silverton volcanic series)	Henson tuff.	Th		75	Fine-grained greenish tuff, of andesitic and latitic material, well stratified and nonfossiliferous. Greatest known development is in the Lake City quadrangle.
TERTIARY (Silverton volcanic series)	Pyroxene andesite.	Tpa		60–2500	A succession of andesite flows and tuffs, characterized by both augite and hypersthene. Greatest known development is in the central part of the Silverton quadrangle. In the Ouray quadrangle only flows are known to occur.
	UNCONFORMITY				
TERTIARY (Silverton volcanic series)	Burns tuff.	Tb		100	Fine-grained dark-green latite tuff containing lenses of impure limestone. Scanty fossil leaves and shells in calcareous layers.
	UNCONFORMITY				
TERTIARY	San Juan tuff.	Tsj		3000	Almost exclusively andesitic débris. Near the base is a well-stratified tuff which becomes coarser and less distinctly bedded in its upper portion. Fossils are not known to occur. The beds vary greatly in thickness, owing to irregularity of deposition and to erosion preceding the eruption of the Silverton series. The maximum thickness observed is in the vicinity of Portland Creek.
	UNCONFORMITY				
TERTIARY	Telluride conglomerate.	Tt		25–100	Coarse conglomerate containing pebbles and bowlders of schist, granite, quartzite, limestone, and other rocks of Paleozoic age, with fine sandy limestone locally.
	UNCONFORMITY				
CRETACEOUS	Mesaverde formation.	Kmv		300+	A series of gray or yellowish quartzose sandstones and sandy shales, massive and cross-bedded in the lower portion and containing a number of productive coal seams in the upper portion. Invertebrate fossils numerous.
CRETACEOUS	Mancos shale.	Kmc		1200	Soft dark-gray or almost black carbonaceous clay shale containing thin lenses of impure limestone. Embraces the Colorado group and a portion of the Pierre division of the Montana group. Fossils more or less abundant.
CRETACEOUS	Dakota sandstone.	Kd		100–200	Gray or rusty-brown quartzose sandstone with a variable conglomerate containing small chert pebbles at or near the base. Carbonaceous shale and coal of poor quality locally present. Indistinct fossil leaves occur sparingly.
JURASSIC	McElmo formation.	Jmc		500–800	A series of alternating, friable, fine-grained, yellowish or grayish sandstones, shales, and thin limestones. The sandstones often include flakes of grayish clay or shale. The shales are chiefly green in color but may be pink, dark red, or chocolate-brown. No fossils found.
JURASSIC	La Plata sandstone.	Jlp		100	Two massive, friable, white, cross-bedded, quartzose sandstones with a narrow band of dark limestone or calcareous shale between. The limestone is locally brecciated. No determinable fossils found.
	UNCONFORMITY				
TRIASSIC	Dolores formation.	₸d		100	Sandy marls and fine-grained sandstones and shales of bright-red color with fine limestone conglomerate near the base in which are found teeth and gasteropod shells indicating Triassic age.
	UNCONFORMITY				
CARBONIFEROUS (Permian)	Cutler formation.	Cc		2000+	A series of bright-red sandstones and lighter red or pinkish grits and conglomerates alternating with sandy shales and earthy or sandy limestones of various shades of red.
CARBONIFEROUS (Pennsylvanian)	Hermosa formation.	Ch		1200–2000	A series of grits, sandstones, shales, and limestones of various distribution and development. Grits and sandstones in massive beds predominate in the middle and upper parts of the section, the lower portion consisting of thinner bedded sandstone, shale, and limestone. Numerous invertebrate fossils occur in the shale and limestone.
MISS.	Molas formation.	Cm		0–50	Red calcareous shale and sandstone with pebbles of quartzite, chert, and limestone containing Mississippian fossils, and thin limestone lenses carrying Pennsylvanian fossils.
	UNCONFORMITY				
DEVONIAN	Ouray limestone.	DCo		175	Limestone, lower third shaly with thin quartzites. Devonian fossils in lower two-thirds and Mississippian fossils in upper part.
DEVONIAN	Elbert formation.	De		0–50	Thin limestone, sandstone, and calcareous shale containing Devonian fish remains.
	UNCONFORMITY				
ALGONKIAN	Uncompahgre formation.	Au		8000+	Massive white or smoky quartzite and dark slate, with a few zones in which the rocks alternate in thinner layers. No fossils found.