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GEOLOGY

OF THE

TARRYALL DISTRICT
Park County, Colorado

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BY

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INTRODUCTION

Field Work

Field work in the Tarryall Gulch district was begun in the summer of 1923 by the author and a party consisting of Clifford L. Mohr and Harold A. Hoffmeister. On account of illness, the author was compelled to leave the field before the end of June and thereafter the work was in charge of Mr. Mohr. During the time the party was in the field, a rough preliminary map was made showing drainage lines, roads and trails, mines and prospects, and other features that might be of use in mapping the geology of the region. The map was made by means of the plane table and telescopic alidade, starting from a base line 3630 feet long, measured with considerable care and accuracy, in a level portion of the valley of Tarryall Creek below Marinelli's ranch. This base line was later tied in to a section corner and also with the Colorado and Southern Railroad, thus giving a reasonably accurate horizontal control. In this way, a triangulation net was first constructed between the principal mountain peaks, locations and distances being determined by intersections and scaling, and altitudes by means of the vertical arc. Most of the prominent points were occupied and all locations and distances were checked a number of times to insure as much accuracy as possible. The result was a fairly serviceable base map, which was later used to map the geology. This ended the field work for the summer of 1923, but in the summer of 1924 the author again went into the field, accompanied by Mr. W. E. Richardson, and carried out the plans that had been made for the preceding summer.

By permission of Mr. Louis Marinelli, headquarters for the party on both occasions were established in one of the abandoned cabins of the Fortune Placers Gold Mining Company, near the point where Tarryall Creek emerges from the mountains and flows out upon the plains of South Park. From this point all of the territory covered by the map could be reached with little difficulty.

Location and area

The area covered by this report lies in Park County, Colorado, about five miles northwest of Como, a station on the Leadville branch of the Colorado and Southern Railroad. It embraces about 35 square miles, bounded on the south by Mt. Silverheels, on the west by the Continental Divide as far north as Boreas Pass or Breckenridge Pass, on the northeast by the irregular range of hills between Michigan and Tarryall creeks, and on the east by the plains of South Park. The location with reference to other mapped areas of the state is shown on the sketch map (Plate 1). The Colorado and Southern Railroad crosses the

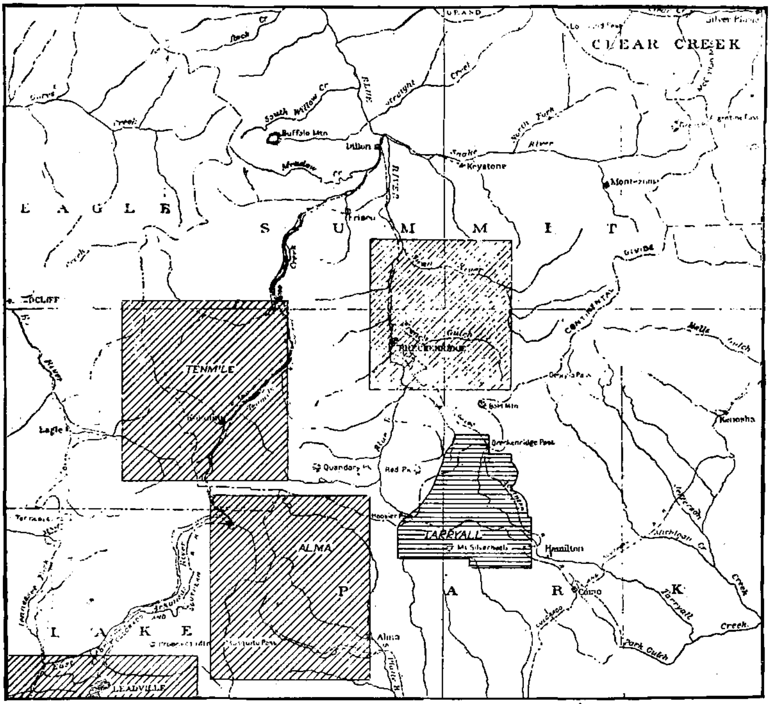

Plate 1. Map showing location of Tarryall district.

district near the eastern edge, and crosses the Continental Divide at Boreas Pass.

Acknowledgements

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Colorado, the author is indebted for many helpful suggestions before going into the field, and also for material loaned for study in connection with the preparation of the manuscript. Further acknowledgement is due Messrs. Mohr and Hoffmeister for the way they carried on the preliminary work during the author's absence, thereby saving him much valuable time and labor in the preparation of the base map, and to Mr. W. E. Richardson for assistance in the field during the summer of 1924. Mr. I. B. Look of Denver, and Mr. Louis Marinelli of Como also deserve acknowledgement for information given, and help rendered while the field work was in progress.

History

Mining began in Tarryall Gulch in 1860, a few miles from where Como is now located. So far as can be ascertained, this was the first place where actual mining was carried on in the entire area known as South Park. These first miners are said to have been men from Wisconsin, and other middle western states, who were enroute to Leadville, but having become wearied by the long journey decided to stop here and rest a while, hence the origin of the name Tarryall.

Placer mining activities were carried on intermittently for many years, and Hamilton, a mining town of some size, sprang up at about the point where Tarryall Creek flows out into South Park. Dr. A. C. Peale in his report, as geologist of the South Park Division of the Hayden Survey,[1] in 1873, credits Hamilton with having had a population of about 5000. Various other reports as to the number of inhabitants are current, but all are probably greatly exaggerated.

About this time, labor troubles at Leadville are said to have been responsible for a party of about forty Chinese laborers coming to Tarryall Gulch. These men were driven from Leadville, and crossed the divide into the headwaters of Middle Tarryall, where they went to work washing gravel.

During the "Seventies" and "Eighties", lode mining was started in a number of places, and several small stamp mills were erected, but these ventures all turned out disastrously, and the undertakings were eventually all abandoned. It is said that several carloads of ore were shipped to Alma, and some to Denver, but no authentic evidence can be had supporting this rumor.

1Hayden, F. V. United States Geological and Geographical Survey of the Territories, 1873; Report of Dr. A. C. Peale, p. 302.

Placer mining in the gravels along Tarryall Creek, below the junction of the three branches and also in Montgomery Gulch, a tributary to Middle Tarryall, continued intermittently until about 1890, when John Fortune began operating what is now known as the Fortune Placers. After work had proceeded for a number of years by hand, a syndicate was formed and hydraulic mining was undertaken. This continued until 1917, when the cost of labor and supplies became prohibitive. About this time also, the ranchers out on the plains of South Park succeeded in having an injunction served upon the Fortune Placers Gold Mining Company which resulted in shutting down the largest and richest placer in Tarryall Gulch. The complaint of the ranchers was that debris washed downstream by the hydraulic mining operations filled up the irrigation ditches.

From reports and surface indications of activity, it seems probable that half of all the gold produced came from the Fortune Placers. The operations here were the most extensive in the district, and the equipment included miles of ditches and steel pipes to lead the water to the hydraulic giants by means of which the gravel was washed down. (Plate 2).

Other locations operated at this time were the Roberts Placer and the Peabody Placer, below the Fortune, and the Liebelt Placer in Montgomery Gulch, up Middle Tarryall Creek. The Liebelt Placer is said to have ranked next to the Fortune as a producer. While these operations were going on, many shafts were sunk and tunnels driven into the mountain sides in the hope of locating the source from which the placer gold came, but all apparently ended in failures. Among the larger undertakings of this kind were those of the Silverheels Mining and Tunneling Company; the Mineral Ranch Hill Tunnel, now operated by the Illinois Central Consolidated Mining and Milling Company, and the Baxter workings at the head of Montgomery Gulch.

At present no active mining is being done anywhere in the district. A number of men are prospecting and keeping up assessment work on their properties but no shipments of ore have been made for many years. Among the areas actively prospected are Jarvis Gulch, Montgomery Gulch, Little French Gulch and the head of Indiana Gulch near Boreas Pass. On Mineral Ranch Hill a property operated by the Illinois Central Consolidated Mining and Milling Company shows the most development, but the workings are badly caved and not accessible. This is the condition of nearly all the old workings, consequently very little could be learned of the underground condition and of the size and extent of ore bodies.

Plate 2a

Plate 2b

Placer ground on the Fortune property.

Previous Work and Literature

The only previous geologic field work in this district is that of the South Park Division of the Hayden Survey in charge of Dr. A. C. Peale. Dr. Peale made a brief study of that part of Tarryall Creek which lies within the mountain amphitheatre, and ascended Mt. Silverheels where he made a partial section of the rock formations encountered.

The United States Geological Survey has mapped the Breckenridge district, which lies just to the north, and the Colorado Geological Survey has mapped the Alma district to the southwest.

The following publications are the more important ones dealing with this section of the state:

Peale, A. C., Report on the geology of the South Park division; Seventh Annual Report, U. S. Geol. and Geog. Survey Terr., 1873, pp. 194-273; 301-302.

Belcher, Gustavus R., Geographical report on the Middle and South Parks, Colorado, and adjacent country; Ninth Ann. Rept.; U. S. Geol. and Geog. Survey Terr., 1875, pp. 419-432.

Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colorado; Prof. Paper U. S. Geol. Survey No. 75, 1911.

Patton, Horace B., Geology and ore deposits of the Alma district, Park County, Colorado; Bull, Colo. Geol. Survey No. 3, 1912.

Crawford, R. D., A contribution to the igneous geology of central Colorado; Am. Jour. Sci., 5th ser., vol. VII, May, 1924.

Topography

The region is one of great relief, having a vertical range of about 4,000 feet. According to the U. S. Geol. Survey, Mt. Silverheels, (Plate 3a) the highest peak, has an elevation of 13,855 feet,

Plate 3a. Mt. Silverheels from Windy Point.

Plate 3b. Slide rock on a porphyry hill.

while the lowest point of the area mapped, about 9,920 feet, is in Tarryall Creek at the east edge of the map. The entire portion of the Continental Divide included in the mapped area has an elevation of over 11,000 feet and many of the high peaks within the area are over 12,000 feet high. The Colorado and Southern Railroad crosses the Continental Divide at Boreas Pass at an elevation of 11,480 feet, according to the U. S. Geol. Survey. A large part of the area lies above timber line, and consequently is subject to rapid erosion (Plate 3b). Many of the high ridges and peaks are covered to a depth of many feet with "slide rock", (Plate 4a and 4b), a name given to slabs and masses of rock de-

Plate 4a

Plate 4b

Spheroidal weathering in quartz monzonite porphyry near top of Little Mountain.

tached as a result of exfoliation. A great thickness of sediments has been removed by erosion as can be seen in ascending Mt. Silverheels. Here the sedimentary beds which form a part of the mountain mass stand at an average angle of about 30 to 35 degrees, and represent the lower part of a huge fold. Together with the intruded sills these beds have a total thickness of between 10,000 and 12,000 feet. Assuming that they once formed a continuous arch over the Mosquito range, it is evident that a thickness of strata equal to about two miles has been removed. This estimate takes into account only those beds below the Dakota sandstone. How much of the Cretaceous section above the Dakota was at one time present is not known, nor is it known how many feet of Tertiary sediments covered the region, but that they were at one time present is shown by remnants here and there. In spite of this enormous amount of erosion, the topography has hardly reached the stage of maturity. In many places there still remain broad rolling uplands, and the valleys are all steep and narrow, except where normal development has been modified by glaciation. The broad rolling uplands which characterize the region and which are especially noticeable along the Continental Divide are perhaps remnants of an older erosion surface or peneplain. W. T. Lee[1] in a recent paper has discussed the peneplains of the Rocky Mountains and mentions this possibility, and it is also suggested by Ransome[2].

Although the Tarryall district has considerable relief, the mountains are not particularly rugged. Except for the higher porphyry peaks which are covered with vast quantities of slide rock, and the Mt. Silverheels side of Montgomery Gulch (Plate 4c), which is formed by the scarp slope of the great series of sedi-

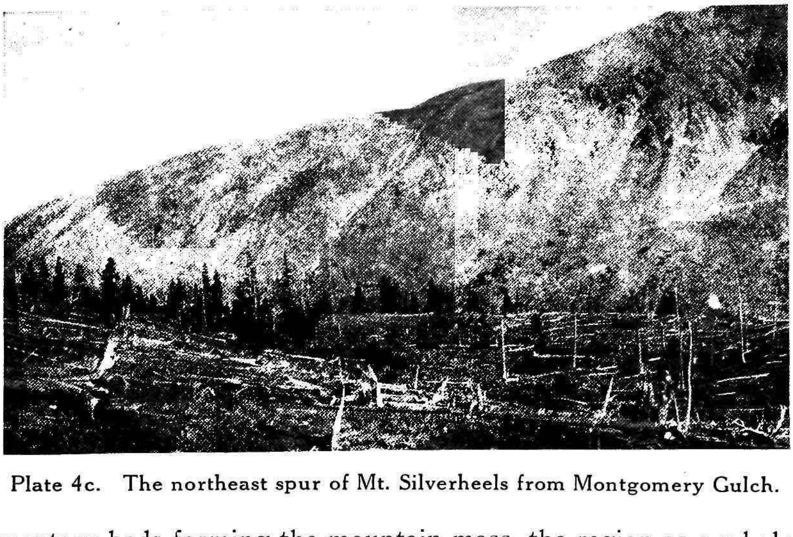

Plate 4c. The northeast spur of Mt. Silverheels from Montgomery Gulch.

mentary beds forming the mountain mass, the region as a whole represents a rounded and rolling topography (Plate 5a). Glaciation has played some part in this development, rounding out the valley heads and partially filling the middle portions with moraines, but on the whole it has not been a very important factor. Much of the rounding is the result of normal erosion, and the ac-

1Lee, Willis T. Peneplains of the Front Range and Rocky Mountain National Park, Colorado; Bull. U. S. Geol. Survey, No. 730-A.

2Prof. Paper, U. S. Geol. Survey, No. 75, 1911, p. 15.

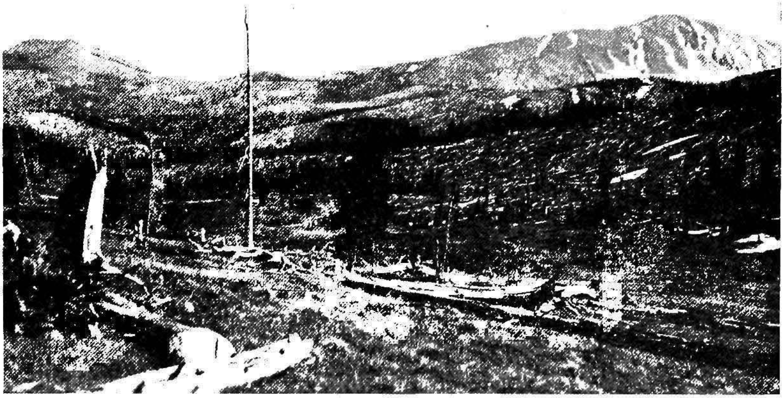

Plate 5a. Looking south from near Windy Point. In the background Little Bald Mountain (on the left) and Mt. Silverheels.

cumulation of residual material along mountain slopes and in valleys. A very notable feature, and one which rendered the field work difficult, is the great abundance of residual debris over the surface, consisting of slide rock and the decomposed and disintegrated products of rock weathering, which effectually hide much of the bed rock.

The Tarryall district is drained almost entirely by Tarryall Creek and its tributaries. About a mile above the point where it flows out on the plains of South Park, this creek forks into three branches. The north branch heads in the Continental Divide at Boreas Pass and Warrior's Mark Mt., the south fork originates in the east spur of Mt. Silverheels, while the middle branch again forks, Montgomery Gulch heading on the west side of Mt. Silverheels, and Little French and Deadwood gulches originating in the Continental Divide near Red Mountain. Drainage from the eastern part of the area goes into Michigan Creek, which joins Tarryall some distance from the mountains, and the combined streams then cross South Park and join South Platte River.

Climate and Vegetation

In a region of such high altitude the summers are naturally cool and short and the winters long. During the field season of 1924, thermometer readings were frequently noted and recorded and these show that the temperature rarely rises above 70° or 75° F. during the day, and often drops below freezing during the night, even in July and August. The winter snow is usually heavy, and snowfalls occur on the mountain tops even in summer. Many areas of permanent snow are found on the higher peaks in places where the direct rays of the sun do not strike.

Timber, consisting largely of spruce, pine and fir, with patches of quaking asp scattered throughout, covers large portions of the mountain slopes and valleys. Most of the area lies within the Leadville National Forest Reserve, and as such is under supervision of forest rangers. Enormous quantities of timber are destroyed almost annually by heavy windstorms, and as a result of former forest fires many square miles are covered thickly with fallen trees. Deadwood Gulch received its name from the great quantities of such dead timber.

In those valleys in which glacial and landslide debris has caused a partial obstruction, soil has accumulated to a considerable thickness, and this supports a dense growth of willow brush and grass together with great quantities of moss. This vegetation accumulates from year to year and in places peat-like bogs have formed to a thickness of from four to six feet. Over much of the surface of these bogs the growth of willow is so dense that it defies penetration, and where passage is possible, one sinks up to his knees, and often deeper, into the water saturated moss.

The lower mountain sides and valleys which are not covered with timber or willows support a rather abundant growth of grass, suitable for grazing; and even on some of the higher slopes above timber line, at 11,500 feet, sufficient vegetation grows to make possible the grazing of large flocks of sheep. Every summer from 10,000 to 15,000 or more sheep are brought up from the ranches in South Park and allowed to graze in the upper parts of the valleys of Tarryall Creek and its tributaries.

General Geology

SEDIMENTARY ROCKS

General Stratigraphic Summary

That portion of central Colorado adjacent to the Tarryall district has a rather complete section of stratified rocks from the Cambrian to the Cretaceous. While no formations older than upper Pennsylvanian occur in the immediate area, they are known just over the Continental Divide to the west. In order to give a better understanding of the stratigraphic succession of this portion of the Rocky Mountain region, it is thought advisable to include here a tabular summary of the geology of neighboring areas. This is taken from F. L. Ransome's monograph on the Breckenridge district, and to it has been added the summary of the Tarryall section.

As the Tarryall district lies farther east than the areas summarized in the table, there is exposed here only the upper part of the succession described in the various reports. Farther east on the plains of South Park are encountered still younger Tertiary formations. Naturally, on account of the location, it would be expected that the sedimentary rocks of the Tarryall district would conform quite closely with those of the Breckenridge area, and a study of the accompanying chart will bear this out. Alma and Leadville are stratigraphically too low for the younger rocks to appear, because they are located about on the axis of deformation. Tenmile has some of them, while Aspen, on the opposite side of the uplift, has the complete section.

Correlation of the beds in the Tarryall district with those of the foothills on the east flank of the Rocky mountains is difficult. The Dakota sandstone can be easily recognized, and is probably the equivalent of the Dakota in the foothills region. The underlying Red-beds, however, present a different problem on account of the absence of characteristic fossils. Most geologists who have studied these beds in different parts of Colorado agree in the assumption that they are at least very nearly the equivalents of the Red-beds in the Denver Basin[1]. If this correlation is cor-

[1]Girty, G. H. The Carboniferous formations and faunas of Colorado; Prof. Paper U. S. Geol. Survey, No. 16, 1903, p. 190.

rect, the Maroon formation of the Tenmile and Aspen areas, and the Wyoming of the Breckenridge area, are in part equivalent to the Fountain, Lyons, Lykins, and Morrison of the foothills of North Central Colorado, and possibly also to the Gunnison and McElmo formations of the western slope.

Henderson[1] at present regards the Fountain and Lyons as Pennsylvanian, and the Lykins as Pennsylvanian, Permian, or Triassic. The Morrison he says is upper Jurassic or lower Cretaceous, with the evidence favoring the former.

The subdivisions of Henderson and others in the foothills region can not be carried out in the area under consideration. In the first place, the exposures are too limited and discontinuous to be traced for any great distance, and, in addition, the sedimentary series has been so much cut up and metamorphosed by igneous intrusions, that correlations with distant formations even on the basis of lithologic character is out of the question, and subdivision is equally impossible.

It seems quite likely that the brick red shales and sandstones which underlie the Dakota belong to the Morrison formation, but how much more of the series belongs here is difficult to say. These brick red sandstones and shales grade downward into darker red and chocolate colored shales and sandstones which are probably the equivalent of the Wyoming of Ransome[2] and Emmons[3], and the Triassic of Spurr[4]. Below this is a thick series of alternating beds of shale, sandstone, and arkose, varying in color from gray through pink to dark red. These are probably the equivalent of the Maroon.

Just where the line between the Maroon and the Weber formation should be drawn is problematical. Above the Weber in Emmons' Hoosier Pass section lies a thick series of sandstones and shales, lithologically quite similar to the Weber, but differing greatly in color. The Weber is usually gray, but the beds resting on it are dark red, although in places various shades of pink and gray are encountered. This formation is generally known as the Maroon. It appears to be conformable above the Weber, and the change from the one to the other is so gradual that no exact line can be drawn, unless one were to take Ransome's[5] suggestion

1Henderson, Junius. The foothills formations of North Central Colorado, Bull. No. 19, Colo. Geol. Survey, 1920.
2Prof. Paper U. S. Geol. Survey No. 75, 1914, pp. 26-42.
3Tenmile district special folio, No. 48, Geol. Atlas U. S., U. S. Geol. Survey, 1898.
4Monograph, U. S. Geol. Survey, Vol. 31, 1898.
5Op. cit. p. 29.

TABULAR SUMMARY
CENTRAL

System	Series	Leadville	Alma	Tenmile
		Emmons, S.F., Geology and mining industry of Leadville, Colo., Mon. U.S.G.S., Vol. 12, 1886.	Patton, H. B., Geol. & Ore Deps. of the Alma district, Park Co., Colo. Bull.Colo.Geol. Survey, No. 3, 1912.	Emmons, S. F. Tenmile Dist. special folio No. 48, Geol. Atlas U. S., U.S.G.S. 1898
Cretaceous	Upper Cretaceous			
Jurassic (?)				
Triassic (?)				Wyoming fm. Brick red ss. with some red shale and local coarse cong. 1500 ft.
Carboniferous	Pennsylvanian	Upper Coal Measures		Maroon fm.—Coarse gray and red ss. with assoc. cong. and ls. 1500 ft.
		Weber Grits	Weber Grits. Coarse ss. or grit above, shale grading to qtzt. and calc. shale and ls.below; 2500 feet.	Weber fm. Coarse gray ss. and grit 2500 ft., with carb. shale at base and thin beds of dolomitic ls. 2800 feet.
		Weber Shale		

OF FORMATIONS
COLORADO

Aspen	Breckenridge	Tarryall Gulch
Spurr, J.E., Geology of the Aspen mining dist., Colo., Mon. U. S.G.S. Vol. 31, 1898	Ransome, F.L., Geol. and ore deposits of the Breckenridge Dist., Colo., Prof. Paper, U.S.G.S. No. 75, 1911.	
Niobrara - Gray lime-stone; grades up into Montana formation; 100 ft. Benton—Black calcareous shales, 350 ft., Colorado group.	Upper Cretaceous shale. Dark shales with a few thin layers of limestone and gray quartzite. Contains Benton, Niobrara, and possibly Montana fossils, 3500-5500 feet.	Upper Cretaceous shale. Black carbonaceous shale; thin, black, fossiliferous ls. below. Lower part carries Benton fossils, upper part Niobrara.
Dakota — Massive white sandstone with local variations; 250 feet.	Dakota sandstone — Buff sandstone passing locally into white quartzite with more or less gray shale. May include some Lower Cretaceous and some Morrison formations (L. Cretaceous or Jurassic) 200-300 feet.	Dakota sandstone—Grayish to buff ss. grading into grayish white quartzite locally. Contains a few thin shale and conglomerate beds. 250 feet.
Gunnison fm. Gray or yellow ss., often calc., overlain by reddish, grayish, or varieg. shaly ss., 300 ft.	Not definitely recognized. Some Morrison formation (Jurassic) may be included with the rocks mapped as Dakota.	Morrison Not definitely recognized probably present, but included with the Tarryall formation.
Unconformity Triassic — Red ss., light red below, dark above; 2600 ft.	Wyoming formation. Brilliant red ss. and shales. Probably equivalent or nearly so, to the Lykins of the Boulder dist., Colo., 1000 ft.	Upper Tarryall formation. Bright red sandstone and variegated shales at the top, becoming darker and more chocolate colored at the base, also gray ss. with pebbly streaks, 6,000.
Maroon formation—Dark red grits, and thin shaly ls. Pass gradually into foregoing; 4,000 ft.	Absent	Lower Tarryall formation. Gray to reddish gritty ss. and interbedded red shale. Pebbly and cong. streaks near the base of individual beds. 3,000-5,000 ft.
Weber fm. Thin bedded carbonaceous ls. and calc. shales; 1,000 ft.	Absent	Not exposed

that it be drawn at the first reddish bed. Strata equivalent to the Maroon constitute the whole of the sedimentary series in Red Mountain and neighboring peaks on the western border of the area mapped. The beds have been tilted eastward at an average angle of about 35°. About a mile and a half south of Boreas Pass they cross the Continental Divide, and can again be seen in Indiana Gulch. The tops of Red Mountain, and other peaks along the divide, are composed of a thick porphyry sheet, which was intruded into the sediments. Throughout this area, such porphyry intrusions are common, and increase the total thickness of strata by hundreds of feet. Furthermore, contact metamorphism by these porphyry sills has greatly changed the appearance and composition of the sediments, resulting in the formation of much epidote and some garnet, and giving the rock a greenish gray color, together with a pronounced banding or "ribbon structure" due to the difference in susceptibility of the various laminae to metamorphism. Along with this epidotization, there has been a general baking and silicification, thus making the rock much harder and more resistent to erosion.

Above the Dakota in the northeast part of the area are small patches of black carbonaceous shales. Still higher, stratigraphically, are grayish calcareous beds which in turn grade into dark colored fissile shales that weather light gray on exposure. Just east of Boreas Pass these shale beds are intruded by a great porphyry sill, and northeastward from here, in the hills forming the divide between Michigan and Tarryall creeks, irregular areas of shale can be seen included in porphyry sheets. The lower shale beds, which rest on the Dakota, carry typical Benton fossils, are black in color, and contain thin beds of black carbonaceous limestone. The upper shale beds contain Niobrara fossils, especially **Inoceramus deformis.**

Formations present

The sedimentary formations represented in the Tarryall district are as follows:

Quarternary	Glacial material	
Tertiary (?)	Lake beds	
Cretaceous	Colorado	Niobrara
		Benton
	Dakota	
Jurrasic (?)	Morrison	
Permo-Carboniferous	Tarryall formation	Upper—Wyoming
		Lower—Maroon

On account of the great amount of igneous material intruded into the sediments, and the relatively small area studied, the descriptions herein given probably apply only to a very limited region in and around Tarryall Creek. Estimates of thickness are probably excessive, because of the igneous material, and other characters ascribed to the various beds are also in part the result of metamorphism by these intrusions and are therefore more or less local.

Lower Tarryall Formation

In general the formation is dark red, or chocolate colored, but on closer examination it appears that the red color is very largely confined to the thin bedded, argillaceous members, and that the sandstones are grayish to pinkish, with a red cementing material. This gives a reddish cast to the whole, which, together with the darker red of the shale members, gives the entire series a dull red color.

It is very difficult to define the boundaries but perhaps it is best to place the base at the bottom of the lowest bed with a distinctly red color, although this is an arbitrary boundary. In the Hoosier Pass section, Ransome noted that the Maroon which is the same as the Lower Tarryall formation, was apparently conformable on the Weber. This is probably true over much of this section of the country, and therefore it will be best to accept current usage and draw the line at the bottom of the lowest red bed, as there do not seem to be any other reliable characteristics that can be used. Still more difficulty is experienced at the top, where there is apparently a conformable gradation into the upper bed, and where not even a color line can be drawn. That so thick a series of shallow water (or possibly terrestrial) deposits could be laid down without apparent disconformity seems improbable. Yet, on the other hand, no field evidence has been found in this area to warrant any other alternative. Perhaps this may be explained by the igneous activity which has so broken up the sedimentary beds and changed their character and appearance that it is impossible to carry correlations very far, and difficult to locate stratigraphic breaks. Perhaps also, if detailed mapping could have been done on an accurate topographic base, some other relations might have been brought to light, but under existing conditions it would be unwise to state definitely that the series is either conformable or disconformable.

Lithologically, the Lower Tarryall formation consists of cross-bedded, fine to coarse sandstones, composed essentially of grains of quartz and feldspar with flakes of mica, together with various minor constituents, the whole cemented with silica, calcite, and iron oxide. The quartz grains are usually clear and transparent, although pinkish and amethyst particles were observed. The grains are generally more or less angular, indicating that they have not been transported far, nor worked over extensively by waves. The feldspar is principally white but some of a decidedly pinkish tinge is present. Under the microscope it is seen to consist of orthoclase, microcline, and small quantities of an acid plagioclase. The pink feldspar, where present blends with the gray or colorless quartz, giving to the whole a delicate touch of pink which in many of the individual beds of the formation is much augmented by ferric oxide in the cementing material. Close examination reveals that the red color of the beds is due almost entirely to this cement and to thin films of ferric oxide over the grains, which penetrates any minute cracks which may be present, even the cleavage planes of the feldspars, and permeates the clay particles. Upon digesting a sample of the typical red sandstone in hydrochloric acid, the iron can be removed leaving clear colorless quartz and pinkish feldspars. On the whole, the color of the sandstone varies from almost pure white to gray, pink and red with gray predominating.

In the basal portions of some of the beds, the sandstone is coarse grained and decidedly pebbly, though hardly conglomeratic. There is quite an admixture of pebbles and cobbles ranging in size from less than half an inch to small boulders six or eight inches in diameter. These consist of clear colorless quartz and pinkish feldspar, and occasionally of granite. The feldspar is commonly quite fresh and shows good cleavage. In individual specimens, the quartz and feldspar are intergrown, and resemble the graphic textures of pegmatites, so common in the pre-Cambrian rocks.

Interbedded with the sandstone and constituting about half of the total thickness, are beds of dark red or maroon colored shales. Many of the shale beds are extremely arenaceous, and others are micaceous. The presence of the mica flakes which invariably lie parallel to the bedding causes the shales to split readily into thin slabs. Ripple marks are common and sun-cracks were also observed. Occasionally along with the red shale, are decidedly darker beds verging on black owing to the presence of carbonaceous material. These, however, occupy but a very small part of the section, although according to Emmons[1] they constitute a considerable part of the Tenmile section. Another characteristic feature is the presence of limestone beds of irregular extent and thickness, interbedded with the sandstones and shales. These limestones are usually light gray in color and on exposure weather white, thus giving a striking color contrast, which can be seen at a great distance. In structure they are dense and compact, but often show intricate fracturing. Many of the fractures have been healed with white crystalline calcite. No fossils were found in any of these beds, hence it is impossible to attempt any paleontologic correlation.

The characteristics of the formation as thus described apply only to those portions that have not been metamorphosed by igneous material intruded into it. Metamorphism is widespread, but varies much in intensity. At the contact of the smaller intrusion, little more than a baking or hardening of the shales is noticeable, and the sandstones have hardly been affected. From this minimum it increases in intensity to the maximum, where the sedimentary rock has entirely lost its original character, and now consists of a banded mass of epidote and garnet, impregnated with specularite and magnetite. Generally this type of rock has a decidedly green color, due to epidote which is strongly developed and masks the brown of the garnet. Where the metamorphism has been less intense, the so-called "ribbon rock" has been developed which consists of alternate bands of brownish red, slate-like material, and epidotized shale. This is by far the more common rock in the Montgomery Gulch and Little French Gulch sections, constituting over 50 per cent of the formation.

The number of intruded porphyry sheets or sills in this series of sediments is large. Only the thicker ones are shown on the map but in addition to these there are many others. The thickening of the sedimentary strata by the intrusion of such numbers of sills is well shown along the steep northwest face of Mt. Silverheels. Here the sedimentary beds show a decided fan-like arrangement, the dip increasing in general towards the top of the mountain. At the base, dips of 20 degrees are common, while towards the top these have increased to as much as 35 degrees locally. Along with the increase in dip there has also been a corresponding variation in the direction of strike due to bowing of the strata by thick sills.

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[1]Tenmile district special folio, No. 48, Geol. Atlas U. S., U. S. Geol. Survey, 1898.

The thickness of the Lower Tarryall formation could not be measured, as it was impossible to determine its boundaries, either above or below. In addition, igneous intrusions have so increased the apparent thickness, and caused so much local variation, that it is difficult to even make estimates. The possibility of repetition of beds by faulting with resultant increase in thickness must also be considered. While no direct evidence of important faulting of this nature was found, it is quite probable that some occurs. Along Montgomery Gulch, on the Mt. Silverheels mass, a section was measured which included in the neighborhood of 2,000 feet of strata. Below this is an unknown thickness of beds to the Weber, and above it another unknown thickness of beds to the Upper Tarryall. A conservative estimate would probably be around 3,000 feet, but even though this is conservative, it should be taken with due allowance for the various influencing factors mentioned above. To this there should be added anywhere from 1,000 to 2,000 feet of igneous material, making a total of between 4,000 and 5,000 feet.

Upper Tarryall Formation

It is impossible to define absolutely either the upper or lower limits of the formation. At the base, there is an insensible gradation from the dark red Lower Tarryall into the lighter colored sandstones and shales here designated as Upper Tarryall. Towards the top, this color becomes stronger and brighter until within 150 or 200 feet of the Dakota sandstone it is in places a brilliant brick red. This greater intensity of red is perhaps in part due to the decreasing amount of metamorphism, as it has been noted that the development of epidote and garnet is everywhere accompanied by a loss of color. Above these brilliant red shales, the outcrops are nearly everywhere covered, but in a few places limestone boulders were encountered and here and there small patches of greenish gray and dark shale were noted.

It is possible that this apparent break in the series marks the presence of beds equivalent to the Morrison of the Foothills area, but no beds such as are described there could be identified here. From the highest point of outcrop of the bright red sandstone and shales to the Dakota, the slopes are everywhere covered, and only in the bed of Tarryall Creek just below the Fortune placers and on the hillside northeast of the junction of the middle and north branches of Tarryall Creek, were any of the intervening beds seen. In the former place a fine grained, grayish blue limestone, weathering yellowish and buff, outcrops for a short distance, and is then covered by the stream gravels. In the latter locality a thin ledge of black limestone outcrops in few places. From this limited exposure a number of fossils were collected and submitted to Mr. I. W. Stanton, of the U. S. Geol. Survey, who identified them as a species of Physa. All the specimens collected apparently belong to the same genus. Physa is a common genus of fresh water gastropods, which according to Zittel ranges from the Upper Jurassic to the present. Stanton[1] says,

"In America we have a number of Tertiary and Cretaceous species, the oldest one known to me being found in the Bear River formation of southwestern Wyoming in approximately the position of the Dakota sandstone. I think there is no record of Physa in the Morrison formation, but it would not be surprising if it should be found there since the Morrison does contain Lymnaea and Planorbis, both of which are commonly associated with Physa at the present time."

The horizon from which the specimens came is below the basal beds of the Dakota as exposed along Tarryall Creek, and is therefore probably Morrison.

As already pointed out, the whole series is probably the stratigraphic equivalent of beds in the Boulder district, beginning with the Fountain and extending up to the Dakota, but any attempt at further correlation is unsafe.

There is apparently an unconformity at the top of the series. While no unconformable contacts could be found, the difference in the direction of strike of the two formations is notable. The lower beds strike in general a little east of north and the Dakota strikes slightly west of north, except near the lower end of Tarryall Gulch, where there is a change in the direction of strike to the northeast.

Lithologically the Upper Tarryall consists of dark red sandstones and shales, which in the upper half gradually grade into the brighter red beds referred to above. Many of the sandstone beds are coarse and quartzitic, but almost invariably these are interbedded with finer grained micaceous beds, which in turn pass into sandy shales with mica flakes along the bedding planes. Ripple marks and cross bedding may be observed in numerous exposures, and in the dark red shales, pits resembling rain drop prints are common.

1Personal communication.

The sandstone members are here and there streaked with pebbles of white quartz, and pinkish feldspar, rather haphazardly distributed throughout the quartz sand. Many of them show evidence of fracturing and subsequent healing of these fractures with quartz. The pebbles are not abundant enough to call the rock a conglomerate, but rather tend to make it a pebbly sandstone. Quartz and feldspar are the most abundant constituents, but mica is locally abundant.

No limestone, except that in the cases above mentioned, was noted in this series, but on the surface in several places were found a number of boulders of a bluish gray to black limestone, containing veins of secondary calcite. Whether these represent masses broken off from ledges not now exposed, or whether they are boulders that have been derived from beds of the Lower Tarryall which outcrop higher up on the mountain side can not be definitely stated. The topographic position of the boulders was such that they might have originated in either way, but lithologically they are identical with the rock from which the fossils were obtained. In places outside of the area limestones are known to occur in this formation, so that it is entirely possible that the boulders may have come from outcrops not exposed.

Much of the section has been greatly altered by metamorphism due to the intrusion of large numbers of sills. This has resulted in the formation of epidote and garnet, accompanied by loss of the red color, and a general silicification which renders the rock quartzitic.

The apparent thickness of the sedimentary series has been enormously increased by the sills. This feature, together with the lack of definite boundaries, prevents an accurate statement of the thickness. Moreover, there is the possibility of repetition of beds by faulting. In view of these difficulties only an approximate estimate of thickness can be given, and this is provisionally put at about 6,000 feet, including the igneous material which probably amounts to about 1,000 feet. Assuming that this thickness is correct, there are in the neighborhood of 11,000 feet of sediments and igneous sills between the Weber formation and the Dakota sandstone. The maximum thickness apparently occurs in the vicinity of Mt. Silverheels, and from here north to Boreas Pass there is a gradual thinning of the section. At Hoosier Pass, Ransome[1] has estimated the thickness at about 6,000 feet,

[1] Prof. Paper, U. S. Geol. Survey, No. 75, p. 29, 1911.

but in the southern part of the Breckenridge area he gives 1,500 as the maximum thickness for the Wyoming, and states that if the Maroon and Weber are present they are included in the Wyoming, which a short distance north of Breckenridge also disappears, allowing the Dakota to rest directly on pre-Cambrian with no intervening beds.

Color of the Tarryall Series

A detailed examination of the red shales and sandstones of these beds, in the field, and in the laboratory both megascopically and microscopically shows that the red color is due to films of ferric oxide, coating the sand grains. The quartz, feldspar, and other constituents are not in themselves red. When seen in thin section, the quartz appears colorless, and the feldspar white or slightly pinkish. Mixed with them, of course, are a number of grains which are much more reddish, but on the whole the red color is not inherent in the individual grains but rather in the thin films which surround them, and to some extent also in the cementing material which binds them together. In many instances, ferric oxide itself is the cement and in other cases calcite and silica, impregnated with ferric oxide, form the binder. In a few cases it may be noted that white calcite cementing material surrounds grains which are coated with a film of ferric oxide. Where the constituent grains of the formation are of such a nature as to permit penetration of ferrugenous solutions, the red coloring matter may be seen along lines of weakness, (i. e. cleavage or fracture), or if the material is porous, the whole mass may be impregnated.

From these observations, it is apparent that the red color is not inherent in the original material, and that it was not formed until after the sediment had come to rest, and is therefore secondary. If it had been formed as a result of oxidizing conditions on the original land mass, the thin films would have been removed by grinding and attrition during subsequent transportation. Furthermore, it seems likely that the sediments were laid down in an inland sea or land-locked basin, where the water contained a large amount of ferric hydroxide, brought in by streams draining adjoining land areas in which rocks containing iron were undergoing erosion. The ferric hydroxide in such waters would be precipitated around the sand grains before consolidation, partially cementing the sand. During the process of consolidation ferric hydroxide might also be included in calcareous and siliceous cementing material. Upon dehydration it becomes red, especially where the salinity is high, hence the red color of the sediments. The final consolidation may have occurred at a later time when the highly ferruginous sea had disappeared and uncolored calcite was deposited between the iron-coated grains. That some red beds may be formed by the erosion of pre-existing red formations is of course possible, but it is not believed that this takes place on a large scale, since transportion would result in a loss of the film of ferric oxide. Furthermore, it is not likely that red beds such as those under discussion would be formed on land. This would require deposition as large, broad, alluvial fans. Had this been the case, one would expect to find characteristic fan structures, such as great variation in thickness within narrow limits, and a strikingly linear lensing of beds. These structures are conspicuously absent, and the great extent both laterally and vertically argues against such origin. It does not seem likely that formations of such extent as the Tarryall series could have been deposited as dry deltas with such uniformity.

In conclusion, the presence of red limestone lenses in the series seems to indicate periods of subaerial erosion. It is hard to conceive of conditions under which limestones and red beds could be formed simultaneously. Therefore, it is believed that the red limestone lenses represent either local unconformities or surface oxidation and that the red color in the limestone is the result of the change from ferrous to ferric iron, while exposed at or near the surface. This process of change was observed going on in several places. Near the surface the limestone beds were decidedly red, but with depth the red color gradually gave way to grays, greens, and blues. Furthermore, a case was noted where a red limestone showed in a valley wall. A short distance away in beds that had suffered no dislocation or other disturbance a shaft was sunk to a horizon below the outcropping red limestone. At the corresponding level there was a grayish blue limestone, entirely devoid of red, showing that the high color was due simply to surface oxidation.

This same line of reasoning does not apply, however, to sandstones and shales. Numerous cases are on record where no change is noted in color of such formations. The red beds are just as red below the surface, even to great depths where surface oxidation could not possibly have been active, as they are at the surface, indicating that their color is not due to surface oxidation, but to processes in operation at the time of deposition, or shortly thereafter.

In the neighborhood of igneous intrusions, ferric oxide is locally reduced by magmatic solutions with a loss of color but accompanied by the formation of epidote and garnet.

The Dakota Sandstone

This formation outcrops in an almost continuous belt from the southeast corner of the area, northwest to Boreas Pass. In a few places, it is interrupted by faulting, or cut out or covered by igneous material. It forms the top of Little Bald Mountain in the southeast corner, where it lies on top of a porphyry intrusion. Along the north side of the mountain it forms a prominent eastward dipping hogback, which continues northward with no interruption, except for the gap cut through it by Tarryall Creek. At a point about opposite Halfway station, on the Colorado and Southern Railroad, the formation has apparently been faulted and partly cut out by a porphyry sill. From here on it passes under Upper Cretaceous shale and porphyry, and reappears beyond the Pass in the head of Indiana Gulch and on the side of Warrior's Mark Mountain.

The Dakota sandstone is generally easy to recognize and has been quite definitely and accurately correlated over most of the Rocky Mountain area. According to Henderson[1] it is entirely possible that the lower sandstone and part of the medial shale members of the Dakota, as ordinarily mapped, are Comanchean. The possibility of an inconformity at the base of the Dakota has already been mentioned.

Over most of the area where the Dakota is exposed, it is a hard, fine grained, grayish white, quartzitic sandstone, massively bedded, which on erosion produces a great assemblage of huge blocks along the scarp slopes of the exposures.

At Boreas Pass, the best exposure in the area, the Dakota consists of three distinct members. The upper 50 feet is a massive fine-grained buff-colored sandstone. Below this, there is about 100 feet of sandy limestone, usually gray in color, interbedded with a little dark shale and conglomeratic sandstone. Below this is 50 feet more of buff sandstone, the lower part of which is quite strongly conglomeratic.

1Colo. Geol. Survey, Bull., No. 19, pp. 83-85, 1920.

On the east side of the pass, this section cannot be recognized, partly because the Dakota outcrops are covered by porphyry and surface wash, so that only occasional exposures can be seen. However, over all this area blocks of typical Dakota sandstone and basal conglomerate are scattered about on the surface. This condition is seen nearly everywhere from Boreas Pass down the valley of North Tarryall Creek to its confluence with Middle Tarryall. From about this point on, the Dakota outcrops in a well-defined ridge, which becomes more pronounced all the way down to a point below the Fortune placers, where Tarryall Creek has cut a deep notch across the dipping beds.

There is a decided change in the character of the Dakota from Boreas Pass along the valley of North Tarryall Creek towards South Park. At the exposure where the section was measured it is predominently a sandstone. East of the Pass it changes to a hard gray or buff quartzite, and this quartzitic character is more or less evident all the way down the valley. On the top of Little Bald Mountain, both quartzite and sandstone phases occur. In many places the quartzite has been brecciated and recemented with secondary quartz, mingled with carbonaceous material which at times is so abundant that it gives the rock a black color.

The upper beds of the Boreas Pass section can be traced satisfactorily over most of the outcrops within the Tarryall district, but the lower beds are not well exposed at any place. Most of the outcrops occur in the scarp face of ridges, and the lower beds are covered with detrital blocks of quartzite and porphyry. Apparently, however, the succession is unlike the Boreas Pass section. No evidence was found of the sandy limestones which are there encountered, although the dark shale is probably present, as are the conglomeratic beds. Interbedded with the quartzite, near the top of the formation, in many places, particularly on the mountain side southwest of Boreas Pass, and on the divide between South Tarryall Creek and Jarvis Gulch, are dark shales which contain coaly material. Throughout the upper part, the sandstones contain carbonaceous streaks with plant remains, most of which, however, are incapable of identification.

All along the northwest slope of Little Bald Mountain from the head of South Tarryall Creek to the top, the surface is strewn with large boulders of Dakota sandstone and quartzite. About half way to the top occurs a crushed zone where the rock is much more finely broken up and highly ferruginous and quartzitic. The fresh quartzite here is fine grained and grayish blue in color, but on weathering becomes yellowish, brownish and finally reddish. Most of the blocks on the surface show beautiful slickensiding, and a very high degree of polish. Apparently a fault zone extends along the west side of the mountain and the boulders and blocks have been dislodged from the escarpment by erosion. As one approaches the mountain top, the blocks become larger and more numerous, until finally on top there is nothing but a tumbled mass of huge blocks some measuring as much as 20x30x50 feet in size. No outcrops in place were observed, all being apparently hidden by this detritus. Where the sandstone is slightly calcareous solution along joints and bedding planes, and on the exposed surfaces, is pronounced. The surfaces of blocks often present a miniature karst topography due to pitting and channeling by the solvent action of water.

Many of the blocks show coatings of iron oxide, and the outer portion, to a depth of as much as two inches, is impregnated and stained with the same material, producing an effect of case hardening or desert varnish.

The thickness, where it could be determined, ranges from 175 to 200 feet and seems to be fairly constant.

The Colorado

Both members of the Colorado formation are thought to be represented. Fossils found in a black bituminous shale, and in associated beds of black fetid limestone above outcrops of recognized Dakota, were identified as typical Benton forms[1]. Among those found were:

PELECYPODA

Ostrea lugubris, Conrad
Inoceramus labiatus, Schlotheim
Inoceramus dimidius, White
Inoceramus fragilis, Hall & Meek
Trigonarca depressa, White

CEPHALOPODA

Scaphites warreni, Meek & Hall
Prionocyclus wyomingensis, Meek

1Professor J. Bridge of the Missouri School of Mines identified fossils for the author.

Stratigraphically higher in the series were found fragmentary specimens of *Inoceramus deformis*—Meek, with attached specimens of *Ostrea congesta*—Conrad, both typical Niobrara forms. The exact position of these with respect to the Benton fossils or with respect to the Dakota sandstone could not be determined, since igneous intrusions have disturbed the strata considerably, and the fossils were obtained from localities several miles apart, with the intervening strata cut out by the igneous material. From these fossils it seems probable that part of the dark shale included in the porphyry on Little Mountain and nearby places is Niobrara as well as Benton, but it is not possible to recognize any division because of the limited extent of the outcrops, and the disturbance to which the beds have been subjected.

The distribution of the Colorado shale is very irregular. The largest area is near Boreas Pass. Here it consists of beds of fine-grained gray sandstone, and a few thin limestones interbedded with a great thickness of dark shales. Just east of Boreas Pass there is intruded into these beds a thick porphyry sill which constitutes the greater part of Mt. Baldy, Little Mountain, and the other peaks which form the divide between Tarryall and Michigan Creeks. This sill, with a number of offshoots from it, has so disturbed the shale that no estimate of thickness could be made.

Along the edge of South Park, in a number of places, outcrops of black shale occur, usually more or less isolated and largely covered by porphyry debris. On the ridge extending from Little Bald Mountain towards Como, several outcrops are found, and in a number of prospect holes, dark shale and black, fetid, fossiliferous limestone can be seen. From these occurrences some of the fossils mentioned were obtained. Another small area occurs just at the end of the ridge between Jarvis Gulch and Middle Tarryall Creek. This is probably the remnant of a down faulted block, as there is evidence of considerable disturbance. Other small patches occur here and there, included in the porphyry which occupies the northeast part of the area, but it was found impracticable to show them on the map. On the whole, metamorphism of the Colorado shales has been much less intense than that of the red beds. Along Selkirk Creek and on the neighboring mountain sides were noted several instances of baking and silicification, with the development of a hornstone-like material at the immediate contact, but epidotization and garnetization so common in the lower formations is not visible.

In conclusion, the Colorado formation of the Tarryall district is so disturbed and cut up by igneous activity that it does not present its true characteristics, and attempts to divide it into Benton and Niobrara, consistent with such division elsewhere, is impossible. Furthermore, no accurate estimates of thickness can be made because of igneous intrusion.

Tertiary Lake Beds

In a few places deposits were encountered that may represent Lake Beds. The best exposures are on the flanks of Little Mountain at Boreas Pass and along the railroad track near Marinelli's ranch.

These deposits vary from coarse conglomerates to fine sandstones, shales and marls. The boulders of the conglomerates are sometimes a foot or more in diameter, and consist of porphyry, red sandstone, and metamorphosed phases of the red beds. In color they range from dark red to greenish gray, depending upon the color of the rocks from which they were derived. Great variation in size of the constituents occurs within very narrow ranges, and single beds often exhibit lateral gradation from one extreme to the other within a few feet. Stratification is fairly well developed, and the explanation that they were laid down in bodies of water as delta deposits seems plausible, although they may represent terrestial deposits. The character of much of the material, and the gradation from coarse to fine permit either conclusion but the presence of marls points to a lacustrine origin. While the areal distribution of these beds is very limited, their position and relation to the other formations is rather significant, inasmuch as they lie with angular unconformity on the older beds and have themselves been tilted as much as 20 or 25 degrees from the horizontal. The importance of this fact will be treated more fully in connection with the geologic history of the region.

Quarternary Deposits

Quarternary deposits are of no great importance in the Tarryall district, but there is distinct evidence that glaciers once occupied the heads of North and Middle Tarryall creeks and their tributaries (Plates 5b and 6a).

Plate 5b. Terminal moraine in Little French Gulch.

Plate 6a. Looking north in the valley of North Tarryall creek toward Mt. Baldy, showing the partial filling of the valley with glacial outwash material.

Glacial debris, mixed with stream gravels, extends all the way down both stream valleys and is particularly abundant at the Fortune placers and opposite Mineral Ranch Hill in Montgomery Gulch, a tributary of Middle Tarryall Creek.

The glacial deposits consist of boulders of all sizes mingled with sand, gravel, and clay in all proportions. At the junction of Middle and North Tarryall creeks these deposits are better developed than anywhere else along the creeks. Here can be seen an unassorted, unstratified mass of boulders and sand, attaining a thickness of about 40 feet. Many of the boulders show striations and grooves characteristic of glacial material, and in addition, the great majority are subangular, or planed off on one or two sides only. Along the lower end of the ridge forming the divide between the two creeks, occurs a terminal-medial moraine formed at the point where the glaciers came together, depositing irregular ridges of boulders and gravel. Below this ridge the material has been modified considerably by post glacial stream action, and consists in part of glacial moraine, and in part of outwash material which shows a rough stratification.

No attempt has been made to map the glacial deposits separately, since they are of limited extent, and are mingled in part with stream deposits. Towards the heads of the valleys the covering of drift is very thin, and does not hide the bedrock. In their lower portions, the deposits are thicker, but even here bedrock comes to the surface in many places.

The glacial material is in general subangular, and varies in size from coarse gravel to boulders 3 and 4 feet in diameter. Most of the pebbles and boulders have been derived from the porphyry intrusions and on account of superior hardness, have resisted erosion better than the sedimentary rocks. Mingled with the porphyry boulders, are many representing the metamorphosed phases of the sediments. Silicified sandstones and shales with epidote and garnet are abundant, and easily recognized by the greenish color. Micaceous sandstones of the red beds are present; and also occasional masses of shale. Among the more unusual types, are cobbles and small boulders of magnetite, which undoubtedly came from the veins and contact zones associated with the porphyry intrusions. There is enough clay to serve as a binder for the coarser material so that wherever excavations have been made the walls stand for a time with perpendicular faces.

The glacial deposits are naturally confined to the valleys, and very largely to the middle portions, thinning rapidly towards the heads where they are absent or covered by more recent hillside wash. Down the stream they grade into glacio-fluvial gravels, in which most of the placer gold has been found, mingled with quantities of black sand.

No attempt has been made to distinguish between the so-called terrace gravels, and the low level gravels. Both types are found, but they are not distinctly separated because the terrace gravels are in large part obscured by more recent hillside wash.

Petrography of the Igneous Rocks

Quartz monzonite porphyry (Plates 6b and 7a and b)

Definition. Porphries are igneous rocks which contain phenocrysts of one or several minerals, in a finer grained or only partly crystallized groundmass. When approximately half or more of such a rock is composed of phenocrysts, the term porphyry is applied, prefixed by the name of the mineralogically equivalent holocrystalline rock. Therefore this rock having the composition of quartz monzonite[1] is designated a quartz monzonite porphyry.

Occurrence. The greater part of the Tarryall district lying northeast of the Colorado and Southern railroad is made up of a great sill of quartz monzonite porphyry, intruded into the Cretaceous shales. The same type of rock is found on Little Bald Mountain and in many other places in smaller sills, and a slightly different facies forms the hill within the loop of the railroad just after crossing Tarryall Creek at the mouth of the gulch.

[1]The name quartz monzonite is used in this report to include those rocks whose feldspars consist of orthoclase and plagioclase in proportion of a third to a half orthoclase and the remainder plagioclase. The plagioclase, however, must be of the soda-lime series. If the feldspar is almost exclusively of the alkali variety, even though it may be in large part albite, the rock is put in with the granites.

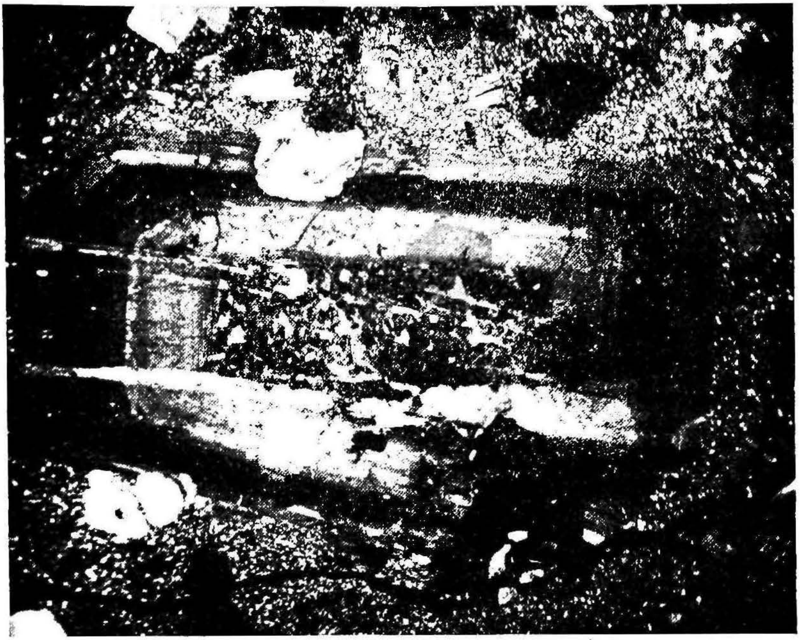


Plate 6b. Large phenocryst of plagioclase from quartz monzonite porphyry, showing strong zonal structure. The central portion is an aggregate of quartz and feldspar. Crossed nicols, x 20.

Plate 7a. Quartz monzonite porphyry. Crossed nicols, x 25. Shows large phenocryst of quartz partially resorbed, and several crystals of plagioclase.

Plate 7b. Quartz monzonite porphyry. Crossed nicols, x 25. Shows broken plagioclase crystal and quartz partially resorbed.

Description. This rock is quite uniformly gray in color, but variations from light gray to dark gray may be seen. Megascopically, the texture is finely granular with a few larger crystals of feldspar, but on the whole it does not appear to be porphyritic. Orthoclase, plagioclase, biotite, quartz, and hornblende can be readily recognized. Both orthoclase and plagioclase are prominent, and the latter can easily be detected by the twinning. Biotite leaves are common, and sometimes distinct prismatic crystals are seen, distinguished from hornblende by the basal cleavage. Hornblende is sparingly found in small acicular crystals. Quartz is abundant among the phenocrysts in rounded grains, characterized by the usual vitreous lustre which is in notable contrast with the duller, more stony lustre of the feldspars.

Under the microscope the rock appears to be distinctly porphyritic. The minerals observed in hand specimens constitute the phenocrysts which are contained in a finely granular groundmass of quartz and orthoclase, with small amounts of biotite, plagioclase, and hornblende. It is also quite evident from thin sections that all the minerals recognized in hand specimens belong to the same period of crystallization, and that there is a sharp distinction between phenocrysts and groundmass.

In thin sections of this rock, orthoclase, plagioclase (oligoclase-andesine), quartz, biotite, hornblende, magnetite, apatite, zircon, titanite and pyrite, are present in nearly all cases, and in one or two, allanite was noted. In the altered varieties, in addition to the above, calcite and a little chlorite and sericite may be seen.

Of the feldspars, plagioclase is more abundant than orthoclase. The crystals are subhedral to anhedral, and show twinning according to the Carlsbad and Albite laws. Zonal structure is common with a difference in extinction angles for adjacent zones up to 5 degrees (Plate 6b). Judging from the index of refraction and the extinction angle, it belongs to the oligoclase-andesine series. Biotite and quartz are poikilitically inclosed in many crystals, and occasionally titanite is so found. Frequently crystals are broken, or fractured, and slightly bent, and others show an outer rim of decidedly more acid feldspar than the interior.

The orthoclase crystals are as a rule not quite as large as those of plagioclase. The former are cloudy and turbid, in contrast to the clear fresh appearance of the latter. Most of the orthoclase is untwinned, though occasionally a Carlsbad twin is seen. Crystal outlines are subhedral to anhedral.

The quartz phenocrysts show much resorption and magmatic corrosion. Grains with large embayments are a striking feature under the microscope. Most of the phenocrysts show no bounding planes, but occasionally perfect hexagonal and bipyramidal sections are seen. Poikilitically enclosed crystals of plagioclase and biotite are common, while around some, rims of sericite have formed.

Hornblende and biotite generally occur in small phenocrysts and present only the usual features. A small amount of chlorite has formed around them, as a result of alteration. The hornblende is usually green, and shows marked pleochroism while the biotite is characterized by strong absorption.

Of the accessory constituents, magnetite, and perhaps ilmenite, are most abundant. Apatite, titanite, and zircon are present in small quantities, and show their usual habits. Not all of these are present in every section, but they are sparingly distributed throughout the rock mass. Allanite, a rather rare mineral, containing several of the rare elements, was noted in a few slides.

The groundmass of the rock is variable in appearance. In some cases it is merely an aggregate of quartz and orthoclase, and again it may contain also biotite and hornblende. On the whole it is microgranitic.

Chemical Composition. The following analyses represent the chemical composition of this rock. The specimens analyzed came from different localities, but the similarity is marked.

	1	2	3	4	5	6
SiO_2	65.38	64.44	66.71	68.14	66.67	68.34
Al_2O_3	17.54	16.97	15.04	15.29	16.72	16.96
Fe_2O_3	2.14	2.79	0.92	0.35	2.54	0.44
FeO	1.72	1.31	1.74	1.66	0.72	1.62
MgO	1.51	1.70	1.53	0.26	1.47	1.94
CaO	2.90	2.88	2.92	3.03	3.03	3.12
Na_2O	3.82	3.77	3.37	3.59	3.67	3.25
K_2O	2.98	3.04	5.04	4.07	3.10	2.49
H_2O+	0.89	1.32	0.43	0.39	1.05	1.12
H_2O-	0.20	0.28	0.34	0.40	0.13	0.05
TiO_2	0.50	0.40	1.29	0.36	0.30	0.40
CO_2	...	1.75	...	...	...	...
MnO	...	...	0.46	0.12	...	0.26
Others	...	...	0.24	1.99	...	...
Total	99.58	100.65	100.03	99.65	99.40	99.99

1. Quartz monzonite porphyry, near Halfway, Colo. H. W. Mundt and A. L. Cairns, analysts.

2. Quartz monzonite porhyry, north of Halfway, Colo. H. W. Mundt and A. L. Cairns, analysts.

3. Quartz monzonite porphyry, Clover Mountain, Colo. R. M. Butters, analyst. Crawford, R. D., Bull, Colo. Geol. Survey No. 4, 1913, p. 158.

4. Quartz monzonite porphyry, Browns Gulch, Breckenridge district, Colo. R. C. Wells, analyst. Ransome, F. L. Prof. Paper U.S. Geol. Survey, No. 75, 1911, p. 45.

5. Quartz monzonite porphyry, Little French Creek, Tarryall district, Colo. H. W. Mundt and A. L. Cairns, analysts.

6. Quartz monzonite porphyry, Mineral Ranch Hill, Tarryall district, Colo. H. W. Mundt and A. L. Cairns, analysts.

Analyses numbers 3 and 4 represent rocks which are very similar to the quartz monzonite porhyry here described, except that large phenocrysts of orthoclase are an important constituent in them. The rocks represented by the first two analyses do not have these phenocrysts. A small mass of porhyry almost identical with the Etna quartz monzonite porhyry of Crawford[1] and the silicic type of quartz monzonite porphyry of Ransome[2] occurs near the eastern edge of the area and is shown on the map northeast of Marinelli's ranch. Unfortunately this mass is entirely detached from other porphyry intrusions, consequently relationships could not be determined.

Other Types of Quartz Monzonite Porphyry

Besides the type above described, which is most characteristic of the quartz monzonite porphyry, and occurs in large masses in the areas mentioned, there are other types which represent local variations. All of them, however, are more or less related and transitional phases between the several types can be found.

With few exceptions, these rocks all have porphyritic habits. In some the groundmass can scarcely be detected megascopically, but under the microscope it is very apparent. In others, the groundmass and phenocrysts can be easily distinguished in hand specimens. The phenocrysts of quartz and feldspar range in size up to a quarter of an inch in diameter, but the majority are smaller. Biotite and hornblende phenocrysts are invariably much smaller. The feldspars and quartz are in general anhedral to subhedral in outline, but the latter also occurs in euhedral crystals and exhibits bipyramidal terminations. In some varieties, large irregularly rounded grains of quartz are visible, and where the rock has been much weathered it is sometimes difficult to tell from a megascopic examination that it is not clastic.

When fresh the color of most of these rocks is light gray to dark gray, and the luster is bright and vitreous, but as weathering progresses the feldspars become dull and biotite and hornblende change to chlorite. Quartz alone remains unchanged, the bright vitreous luster contrasting sharply with the duller luster of the rest of the rock.

1Op. Cit. pp. 155-159.
2Op. Cit. pp. 44-50.

Under the microscope, varying amounts of plagioclase and orthoclase may be seen in the different varieties. In some, the chief feldspar is orthoclase with but little plagioclase, and from this type there are all gradations to those in which the two feldspars are present in about equal quantities. Quartz varies greatly in amount and distribution, being abundant among the phenocrysts in some varieties, and confined almost wholly to the groundmass in others. In nearly every case it shows considerable magmatic corrosion. Biotite and hornblende are nearly always present, but the former more abundantly than the latter. Among the accessory minerals, apatite, zircon, titanite, magnetite, pyrite, and allanite are usually found. The last named mineral is not as abundant as some of the others, but was observed frequently. It is probably present in small amounts in all the porphyries of the district.

Diorite Porphyry (Plate 8)

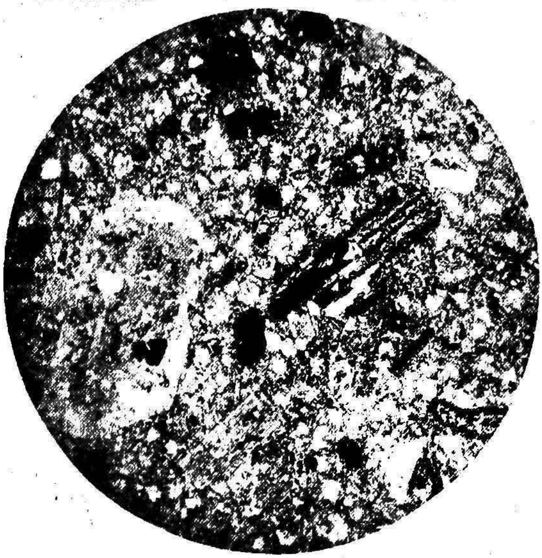


Plate 8a. Diorite porphyry. Ordinary light, x 25. Shows altered hornblende crystals and large phantom crystal of plagioclase.

Definition. A diorite is a granitoid rock consisting essentially of plagioclase and hornblende with more or less biotite and augite, together with various other accessory constituents. Small quantities of orthoclase are frequently associated with the plagioclase.

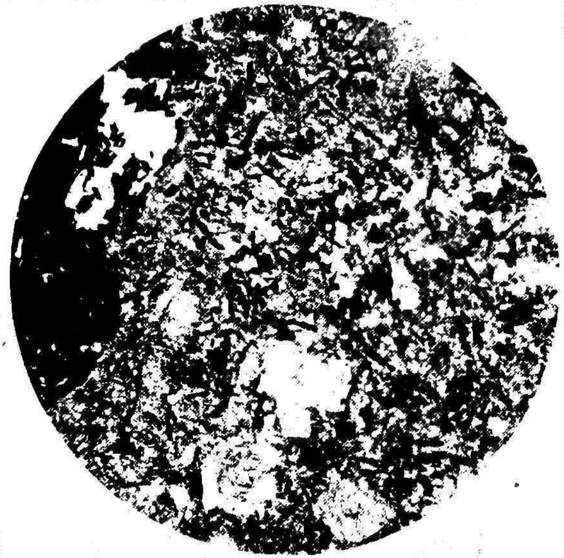


Plate 8b. Diorite porphyry. Crossed nicols, x 25. Shows part of large hornblende crystal and numerous small ones in the groundmass.

A diorite porhyry is a rock with the above mineral composition but with a porhyritic texture.

Occurence. This rock is found in a sill of considerable size near Boreas Pass. It outcrops in the valley of North Tarryall Creek east of the Pass and forms a considerable part of Little Mountain northeast of the railroad. Other small sills were observed in the vicinity of Warrior's Mark and Red Mountain and a few were encountered on Buck Mountain but none of these were considered of sufficient size to be indicated on the map, without undue exaggeration. It seems probable that this rock is the equivalent of the monzonite porhyry described by Ransome[1] in the Breckenridge district and which he regards as equivalent to the diorite at the Wellington Mine.

Description. The rock is dark gray when fresh, but weathering produces a brown iron stain over the surface. Below this surface veneer of brown the weathered rock is greenish gray. In hand specimens the naked eye can detect plagioclase, hornblende and biotite. Biotite is rather uniformly distributed in small flakes and easily detected by its glistening lustre. Hornblende, while

[1]Ransome, F. L., Geology and ore deposits of the Breckenridge district, Colo., Prof. Paper, U. S. Geol. Survey, No. 75, 1911, pp. 50-57.

not particularly abundant, is conspicuous on account of its occurrence in long slender phenocrysts. Frequently two such crystals cross or penetrate each other in the form of an "X". Occasionally clusters of crystals with well developed cleavage occur sparsely distributed throughout the rock. Plagioclase constitutes a part of both phenocrysts and groundmass. The grains are irregular or rounded and without sharp boundaries. An unusual feature of this rock is the presence of garnet in irregular grains and masses. It is not abundant but small amounts may be seen in nearly every specimen. On the whole the rock is not conspicuously phenocrystic to the naked eye.

Under the microscope, all the minerals identified megascopically, can be seen among the phenocryts and in the groundmass. The rock is distinctly porphyritic, but the groundmass is holocrystalline.

Plagioclase is the most abundant constituent. The crystals are subhedral to anhedral but show considerable alteration to carbonate, kaolin, and epidote, even in the freshest specimens. Twinning according to the Albite law is common and cases where such twinning is superimposed on Carlsbad twins may also be seen. Some crystals which show only Carlsbad twinning are present and together with many untwinned ones are probably orthoclase since potash is known to be present in considerable quantity.

Hornblende is abundant as phenocrysts and in the groundmass. Alteration to chlorite and epidote is very common and associated iron oxide suggests that this also is a result of alteration of hornblende.

Biotite is present throughout in irregular flakes, much of it showing alteration to chlorite and magnetite. Very few crystals show the original boundaries but have a frayed appearance resulting from alteration.

In the thin section very little garnet appears, but where observed it shows strong anomalous double refraction. It is possible that it does not represent an original constituent but has resulted from partial assimilation of country rock by the magma.

Sporadic quartz grains were noted among the accessory constituents and apatite is present in the form of needles inclosed in other minerals and as rods and grains in the groundmass. The iron oxide is probably ilmenite or possibly a titaniferous magnetite since the chemical analysis shows 1.4 percent of titania and no titanite was seen in the thin section.

Chemical Composition. The chemical composition of the rock shows that it lies within the range of the andesite-diorite series. Compared with the quartz monzonite poryhyry it shows a considerable increase in the bases and a decrease in the silica. Potash and soda show only a slight decrease. The following table shows the similarity between this rock and a diorite porphyry from the Breckenridge district.

Chemical analyses of diorite porphyrics

	1	2	3
SiO_2	53.60	55.44	57.35
Al_2O_3	17.01	14.95	16.29
Fe_2O_3	4.06	4.37	3.15
FeO	4.81	5.18	4.36
MgO	3.54	3.58	2.41
CaO	5.73	6.12	5.66
Na_2O	3.42	4.44	4.50
K_2O	2.08	2.83	3.39
H_2O+	2.58	0.84	0.70
H_2O-	0.11	0.12	0.15
TiO_2	1.40	1.22	1.07
CO_2	0.84	0.35	0.46
MnO	0.87	0.22	0.12
Others	...	0.78	0.94
Total	100.05	100.44	100.55

1. Diorite porphyry, Boreas Pass, Colorado. H. W. Mundt and A. L. Cairns, analysts.

2 and 3. Diorite porphyry, Wellington mine dump Breckenridge district, Colo. W. T. Schaller, analyst, Ransome, F. L., Prof. Paper, U. S. Geol. Survey, No. 75, 1911, p. 55.

Plate 9a. Silverheels quartz monzonite porphyry. Crossed nicols, x 25. Shows one of the few quartz phenocrysts and abundant plagioclase.

Plate 9b. Silverheels quartz monzonite porphyry. Crossed nicols, x 25. Shows a type in which quartz is nearly absent and in which hornblende is abundant in the groundmass.

Sliverheels quartz monzonite porphyry (Plate 9)

Distribution and name. This type of quartz monzonite porphyry, which forms a large part of Mt. Silverheels and neighboring peaks at the head of Little French Creek, is sufficiently different from the preceding type to warrant separate description. Although in the field it was found impossible to distinguish between the two consistently, some difference could be recognized. It contains more hornblende and less quartz than the first type and in addition contains numerous inclusions resembling a hornblende schist. The more basic character of this rock is also revealed in the chemical analysis which shows less silica and alkalies and a corresponding increase in iron, magnesia and lime.

Description. Fresh specimens of this rock are gray but on weathering readily become greenish due to the development of chlorite and epidote. Most of the feldspar shows little cleavage but occasionally cleavages occur on which albite twinning striations can be detected with the aid of a good lens. Hornblende is abundant in most specimens and small inclusions of a hornblende rock resembling amphibolite are almost everywhere present. Quartz is as a rule not recognizable in hand specimens and biotite occurs but sparingly.

Under the microscope, the rock is seen to be porphyritic with phenocrysts of plagioclase and hornblende and occasionally quartz and biotite embedded in a fine grained groundmass of orthoclase, quartz and hornblende. The quartz phenocrysts are much rounded and strongly resorbed and frequently contain poikilitic plagioclase. Magnetite is present both as an original constituent and as a secondary alteration product. Other alteration products are epidote and chlorite, both abundantly present, the former derived from plagioclase, and the latter from hornblende and biotite.

All specimens examined show considerable alteration, even those which in hand specimens look fresh. In some cases the changes have advanced so far as to obscure the primary minerals with a host of secondary products.

The plagioclase, as determined by the index of refraction and by extinction angles, belongs to the andesine-labradorite series. Twinning after the Albite and Carlsbad laws is common, but much of it is obscured by epidote and other secondary products. The form of the plagioclase varies from anhedral to subhedral with a few nearly euhedral forms enclosed in grains of quartz.

A large part of the groundmass consists of a fine grained aggregate of quartz and a feldspar, presumably orthoclase, while small irregular grains of hornblende make up most of the remainder.

The hornblende is usually brownish or yellowish green, and shows pleochroism to various shades of green. It shows considerable alteration especially to chlorite and is often surrounded by dark rims containing magnetite. This alteration is particularly noticeable in the phenocrysts.

The chemical composition of a representative specimen of this type from the top of the divide at the head of Little French Creek is as follows:

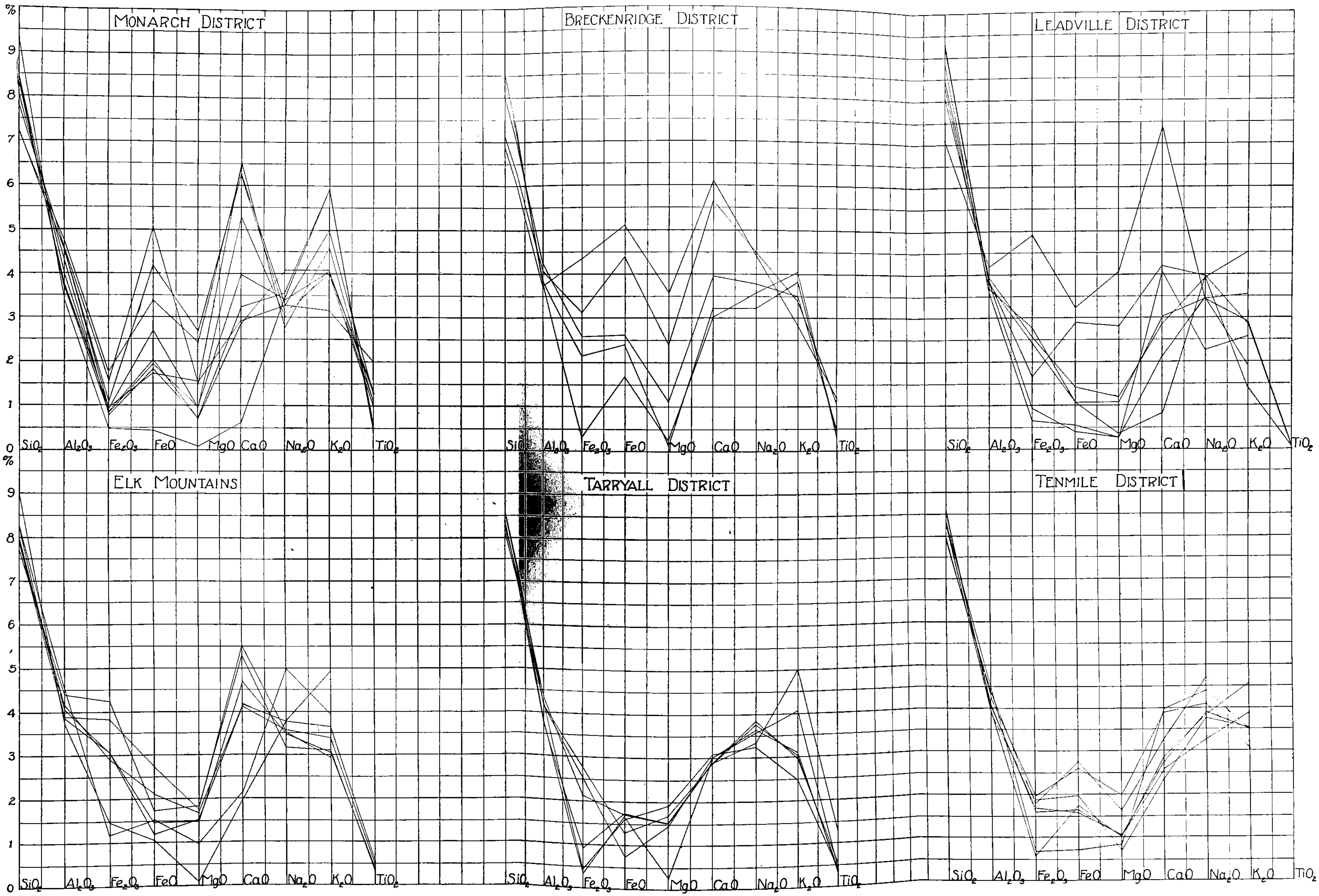
(H. W. Mundt and A. L. Cairns, analysts.)

SiO_2	62.51	Na_2O	3.31
Al_2O_3	17.49	K_2O	1.80
Fe_2O_3	2.52	H_2O+	0.66
FeO	2.80	H_2O-	0.08
MgO	2.27	TiO_2	0.70
CaO	5.08	MnO	0.36
			99.58

Comparison of Igneous Rocks of Central Colorado

The igneous rocks of the Tarryall district are part of the same petrographic province that the rocks of neighboring areas belong to. Thus, for instance, in the Breckenridge district Ransome[1] has distinguished three principal types, a quartz monzonite porphyry, a monzonite porphyry, and a quartz monzonite porphyry of intermediate type. He has also pointed out the fact that they are all closely related and correspond to certain parts of a continuous series, and has further shown that they are in turn related to similar rocks of the Tenmile and Leadville areas.

[1]Prof. Paper U. S. Geol. Survey, No. 75, 1911, pp. 43-62.



Scale: $SiO_2 = \frac{1}{8}$; $Al_2O_3 = \frac{1}{4}$.

DIAGRAM SHOWING VARIATION IN COMPOSITION OF IGNEOUS ROCKS

In the Leadville district, Cross[1] described six main varieties which, however, were classified on a purely local basis depending in part upon the type of alteration which they exhibit, but investigation shows that at least one of them, the Lincoln porphyry, extends beyond the area and is encountered elsewhere. Patton[2] in the Alma district and Howell[3] in the Twin Lakes area have described rocks which as far as mineralogic composition is concerned might very well be closely related to those here dealt with. Cross[4] has shown the similarity between the Lincoln, Elk Mountain and Quail porphyries of the Tenmile area, and in a recent paper Crawford[5] has pointed out the relationships between a large number of rather widely separated occurrences of a monzonite porphyry over a considerable area in Central Colorado and has suggested that they are related to the Princeton quartz monzonite batholith.

With this in mind, the writer has brought together a number of analyses of rocks from neighboring areas, and attempted to show graphically the relationships and similarities between them and the rocks of the Tarryall district[6]. The accompanying charts were constructed by plotting the percentages of silica as ordinates and the percentages of the other oxides as abscissas, for each of the analyses (Plate 10).

Analyses of Rocks from Tarryall District

(H. W. Mundt and A. L. Cairns, analysts.)

	1	2	3	4	5	6
SiO_2	65.38	64.44	53.60	66.67	68.34	62.51
Al_2O_3	17.54	16.97	17.01	16.72	16.96	17.49
Fe_2O_3	2.14	2.79	4.06	2.54	0.44	2.52
FeO	1.72	1.31	4.81	0.72	1.62	2.80
MgO	1.51	1.70	3.54	1.47	1.94	2.27
CaO	2.90	2.88	5.73	3.03	3.12	5.08
Na_2O	3.82	3.77	3.42	3.67	3.25	3.31
K_2O	2.98	3.04	2.08	3.10	2.49	1.80
H_2O+	0.89	1.32	2.58	1.05	1.12	0.66
H_2O-	0.20	0.28	0.11	0.13	0.05	0.08
TiO_2	0.50	0.40	1.40	0.30	0.40	0.70
CO_2	....	1.75	0.84	....	....	....
MnO	....	....	0.87	....	0.26	0.36
Totals	99.58	100.65	100.05	99.40	99.99	99.58

1 Monograph, U. S. Geol. Survey, Vol. 12, 1886, pp. 323-333.
2 Bull. Colo. Geol. Survey, No. 3, 1912, pp. 62-94.
3 Bull. Colo. Geol. Survey, No. 17, 1919, pp. 42-72.
4 Fourteenth Ann. Report, U. S. Geol. Survey, Pt. 2, 1894, pp. 165-241.
5 Crawford, R. D., A contribution to the igneous geology of central Colorado, Am. Jour. Sci., 5th series, Vol. VII, 1924, pp. 365-388.
6 Ransome, F. L., Geology and Ore Deposits of the Breckenridge district, Colorado, Prof. Paper U. S. Geol. Survey No. 175, 1911, pp. 60-62; and Crawford, R. D., Geology and Ore Deposits of the Monarch and Tomichi districts, Colorado, Bull. Colo. Geol. Survey, No. 4, 1913, pp. 185-194.

1. Quartz monzonite porphyry, near Halfway, Tarryall district, Colorado.
2. Quartz monzonite porphyry, north of Halfway, Tarryall district, Colorado.
3. Diorite porphyry, Boreas Pass, Tarryall district, Colorado.
4. Diorite porphyry near Boreas Pass, Tarryall district, Colorado.
5. Quartz monzonite porphyry, Little French Creek, Tarryall district, Colorado.
6. Quartz monzonite porphyry, Mineral Ranch Hill, Tarryall district, Colorado.

The analyses of rocks from the Tarryall district were made for this report. The other rock analyses plotted in the following diagrams were taken from pages 186 to 189 of bulletin No. 4 of the Colorado Geological Survey, by R. D. Crawford.

For convenience of reference the names and localities are here reproduced.

1. Quartz diorite. **Shoshonose.** Lost Mountain.
2. Andesite. **Shoshonose.** Jennings Gulch.
3. Quartz diorite (monzonitic) **Shoshonose.** Monarch.
4. Pomeroy quartz monzonite. **Amiatose.** Pride of the West tunnel, Pomeroy Mountain.
5. Quartz latite porphyry. **Toscanose.** Mohammed tunnel, Middle Fork.
6. Etna quartz monzonite porphyry. **Toscanose.** Clover Mountain.
7. Princeton quartz monzonite. **Toscanose.** Taylor Mountain.
8. Quartz monzonite gneiss. **Toscanose.** Jennings Gulch.
9. Granite. **Liparose.** Browns Gulch.
10. Porphyrite. **Yellowstonose.** Storm Ridge.
11. Diorite. **Tonalose.** Brush Creek.
12. Porphyritic diorite. **Yellowstonose.** Mount Marcellina.
13. Hornblende-mica porphyrite. **Adamellose.** Cliff Creek.
14. Quartz porphyrite. **Amiatose.** Mount Carbon.
15. Quartz porphyrite. **Lassenose.** Crested Butte.
16. Rhyolite. **Toscanose.** Round Mountain.

17. Rhyolite. **Alsbachose.** East Mountain.
18. Diorite porphyry, **Andose.** Wellington mine, Breckenridge district.
19. Hornblende-mica porphyrite. **Andose.** Buckskin Gulch, Leadville district.
20. Diorite porphyry. **Andose.** Wellington mine, Breckenridge district.
21. Diorite porphyry, McNulty type. **Lassenose.** Tenmile district.
22. Quartz-hornblende-mica porphyrite. **Yellowstonose.** Gold hill, Tenmile district.
23. Quartz monzonite porphyry. **Amiatose** near **Yellowstonose.** Mount Guyot, Breckenridge district.
24. Biotite porhyrite. **Tonalose.** North Mosquito Amphitheater, Leadville district.
25. Granite porphyry. **Toscanose.** Jefferson tunnel, Tenmile district.
26. Lincoln porphyry. **Lassenose.** Mount Lincoln, Leadville district.
27. Diorite porphyry. **Yellowstonose.** Copper Mountain, Tenmile district.
28. Quartz porphyrite. **Toscanose.** Sugarloaf, Tenmile district.
29. Quartz monzonite porphyry. **Amiatose** near **Toscanose.** Brewery Hill, Breckenridge district.
30. Gray porphyry. **Yellowstonose.** Johnson Gulch, Leadville district.
31. Quartz monzonite porphyry. **Toscanose.** Browns Gulch, Breckenridge district.
32. Quartz porphyrite. **Lassenose.** Chicago Mountain, Tenmile district.
33. Granite porphyry. **Toscanose.** McNulty Gulch, Tenmile district.
34. White porphyry not fresh). **Riesenose.** California Gulch, Leadville district.
35. Mount Zion porphyry. **Toscanose.** Prospect Mountain, Leadville district.
36. Nevadite. **Liparose.** Chalk Mountain, Leadville district.

A study of these variation diagrams shows quite clearly that most of the rocks are quite closely related and that very probably they all belong to the same general period of volcanism. It is to be expected that minor variations should occur, but the general similarity is quite apparent. Such variations as do occur are no greater than those often encountered in rocks within the same intrusive mass.

The diagrams further show that the difference between rocks of the six districts are no greater than those between rocks of the same region, and from a chemical standpoint it is manifest that all belong to the same petographic province. Mineralogically the same resemblance is noted. This is especially to be seen in the presence of the same accessory minerals, such as apatite, zircon, allanite and titanite, and in the percentages of the different feldspars.

In detail, the diagrams show that the amounts of the several constituents vary irregularly. Apparently, there is no uniform change in any direction. For example, as one constituent in a rock increases, another one decreases, but in the next rock perhaps an entirely different constituent shows a decrease. It is to be noted, however, that alumina and the alkalies remain quite constant throughout the series.

Crawford[1] has discussed the occurrence and distribution of the Princeton quartz monzonite, and has pointed out rather conclusively that many of the apparently isolated stocks are in reality only high points of the same plutonic intrusion which he refers to as the Princeton batholith. In view of the close chemical similarity of the porphyries to the Princeton quartz monzonite, the present writer believes that the Princeton batholith is the plutonic mass from which the sills came and that it underlies most, if not all, of the area under consideration.

Age Relationships of the Porphyries

The age relation of the several kinds of porphyry is a difficult one to settle. While in a few places there is an apparent gradation from one to another, in many other places they occur as separate, distinct sills. Moreover, most of the porphyries occur as sills in the sedimentary rocks, and do not cut one another; hence it is impossible to tell which is the older. A number of dikes of small size occur which cut the sills and therefore are younger.

1Op. cit.

Structural Features and Geologic History

General Structure and Deformation

The most common conception of the structure of the Rocky Mountains in central Colorado is that of two approximately parallel axes of uplift, the one to the east marked by the present Colorado or Front range, and the other to the west by a series of ranges often referred to as the Park ranges, and between these a series of depressions now known as parks. This uplift took place before the Paleozoic since the oldest sedimentary rocks of the region, the Cambrian, lie unconformably upon the Archean. These two land masses remained areas of erosion for a long time, and contributed very largely to the thick sedimentary series now resting upon their flanks, a series which extends from Cambrian to Cretaceous, and which shows no great angular unconformities, therefore indicating that during all this time the region was apparently free from major dynamic movements.

Following the deposition of the Cretaceous beds, and marking the close of the Mesozoic era, there was another period of uplift, during which the Rocky Mountain region was uplifted to about its present position, after which erosion continued and beds of later age were laid down locally with angular unconformity on the Mesozoic strata.

Such post-Mesozoic beds are found in the Tarryall district, but it was impossible to determine their exact age. That they are post-Cretaceous is evident because of their structural relations to beds known to be of that age but whether they are Tertiary or Quaternary can not be told. Their significance lies in the fact that they have been tilted to an angle of about 20 to 25 degrees from the horizontal. It might be argued here that this inclination is original dip and represents the angle at which the sediments were laid down. If it is initial dip the conditions of deposition must certainly have been very unusual. Initial dips of 8 degrees and more are known to occur in torrential deposits and the writer measured dips on accumulations of hydraulic mining debris deposited in water which were even a little larger, but it is doubtful whether initial dips of 20 degrees or more exist in stratified or even partially stratified deposits. Furthermore, the fact that these beds grade into, and are interbedded with marls, is incompatible with the assumption that they are torrential deposits. In consequence we are led to the conclusion that they have been tilted from their original position during a period of deformation subsequent to the revolution marking the close of the Cretaceous.

The exact date of this deformation cannot be determined in this area. In other parts of the Rocky Mountain region similar tilting of post-Cretaceous beds has been noted and there is some indication that it may have occurred during Miocene time but there is also evidence in other areas of tilting and faulting after the first glacial period. In conclusion it may therefore be said that although the age of the tilting movement cannot be settled there is evidence of at least one period of disturbance following the Cretaceous revolution.

Structural Features of the Tarryall District

In the area under consideration we are concerned chiefly with the western uplift mentioned above, and the depression between it and the eastern uplift. The ancient western land mass is now represented by the Sawatch range, and the depression is known as South Park. The present topographic boundary on the west side of the park, the Mosquito Range, is not part of the original uplift but was formed at the close of the Cretaceous.

During most of Paleozoic and Mesozoic time, the present site of South Park was an area of deposition and extended a considerable distance farther west than its present boundary. The Archean land-mass to the west furnished much of the material for the thick sedimentary beds of this portion of central Colorado which range in age from Cambrian to upper Cretaceous. They were laid down in a gradually advancing sea as is shown by the numerous overlaps of younger formations on the pre-Cambrian and on the whole show but little interruption of deposition. The lithologic character of the beds indicates deposition in shallow water, near shore. Although typical conglomerates are not abundant, pebbly streaks in the coarse sandstones are widely distributed and together with ripple marks and crossbedding bear witness of such deposition.

The general structure is that of a huge monocline, the initial eastward dip of the sediments having been greatly increased by the post-Cretaceous uplift which resulted in the formation of the Mosquito range. In detail, however, the structure is far from a simple monocline, as faulting and igneous intrusion have greatly complicated it. On the west in the Leadville and Alma districts the basal beds of the Cambrian rest on the pre-Cambrian but to the north there is progressive overlap until just north of Breckenridge the Dakota sandstone rests on the pre-Cambrian. The eastern boundary of this tectonic block is somewhat obscure. Opposite the Tarryall district it is covered by the sediments in South Park and farther north, opposite the Breckenridge area, faulting has brought Cretaceous beds into juxtaposition with pre-Cambrian. Apparently the whole block has been rotated around a north and south axis to the extent of 20 to 25 degrees since the deposition of the Dakota.

Sedimentary beds on the west side of the Mosquito range probably represent strata at one time continuous over the range but subsequently cut off by faulting and erosion. Still further west these beds are cut by the Mosquito fault described by Emmons[1]. According to Ransome[2], the Breckenridge area presents similar conditions. He says,—"the sediments of the Breckenridge area once extended across the line of the present Tenmile range and were continuous with those of the Tenmile district. Whether prior to their erosion, the beds swept uninterruptedly up over what it now the crest of the range until they reached the Mosquito fault, or whether they were stepped down by intervening faults, has not been determined."

Porphyry Intrusions

The sedimentary rocks have been very intricately intruded and greatly disturbed by igneous material in the form of irregular sills. In a rough way these have followed the bedding but in many places the intruded mass was so great that the original attitude of the beds has been obliterated and new structures imposed upon them by the igneous material. Beds originally in contact have been separated and forced into entirely different relation with each other. As a rule, the overlying bed has suffered a considerable change in the angle of dip and locally also in the direction of strike. The structure on the whole appears laccolithic, except that instead of being horizontal as in the ordinary conception of a laccolith, it is inclined at an angle of about 30 degrees. During the process of intrusion many of the adjacent beds were broken up and fragments of these may still be seen scattered

1Tenmile district special folio (No. 48), Geol. atlas U. S., U. S. Geol. Survey; Geology and Mining industry of Leadville, Colo., U. S. Geol. Survey, 1898, Vol. 12, 1886.

2Ransome, F. L., Geology and Ore deposits of the Breckenridge district, Colo. Prof. Paper U. S. Geol. Survey, No. 75, 1911, p. 63.

in the porphyry as inclusions. In other places faulting accompanied the intrusive processes. Such was the case on Little Bald Mountain where the Dakota is found on top of the mountain at an elevation of over 11,500 feet while a short distance north in the general line of strike on the side of the mountain, it lies at an elevation of about 10,000 feet. The two outcrops are separated by a mass of porphyry which was intruded just below the Dakota and lifted up a large block of it producing a structure resembling a bysmalith. On the north, west and south sides of the mountain, the presence of large numbers of slickensided blocks suggests faulting which probably occurred at the time of intrusion. The fault along the west side of the mountain apparently continues northeastwardly towards Halfway, although it cannot be traced continuously, and beyond this point it is covered by porphyry. Evidence of other faulting was seen in a number of instances but it was found impossible to work out the relations without a more detailed base map.

Inclusions in the Porphyry

A conspicuous feature of nearly all exposures of porphyry is the large number of inclusions or segregations, consisting principally of hornblende. These may represent actual fragments of older rock which the magma picked up on its way towards the surface, or they may represent differentiation products from the magma. Petrographically the evidence favors the first view. Most of the fragments examined are apparently metamorphic rocks of the hornblende schist or amphibolite class. Hornblende with biotite, quartz and feldspar are the chief constituents and these show the same parallelism of arrangement characteristic of schists. The writer is of the opinion that many of these inclusions are fragments of pre-Cambrian metamorphic rock brought up from below by the magma. A comparison of these inclusions with specimens of pre-Cambrian amphibolites showed a striking resemblance between the two. Mineralogically and texturally they are so nearly alike that they can hardly be told apart. Additional evidence that they are fragments of the pre-Cambrian metamorphic series is shown by two specimens which the writer found embedded in porphyry. These specimens are water-worn pebbles, the one a hornblende schist ¾ by 2½ by 2¾ inches in size and the other a highly contorted and intricately crumpled feldspar, biotite gneiss, 2 by 3 by 4 inches in size. Both specimens are such as can be seen in great numbers along any stream in an area of metamorphic rocks. Their position in the porphyry removes all doubt as to the manner of transportation. They must have been picked up by the magma on its way to the surface. Whether they were picked up from the original pre-Cambrian terrane or whether they came from a conglomerate bed somewhere in the sedimentary series cannot be determined. The evidence is in favor of the latter view since pebbles of pre-Cambrian granites are abundant in the conglomerates and there is no reason why pebbles of gneiss and schist could not occur in the same way. Also, since they show no contact effect, one is lead to the conclusion that they were not transported far by the magma. In sharp contrast with the absence of contact effect upon these pebbles, is the effect produced on numerous other inclusions. One can see all steps in a gradation from the unaltered types to those whose former presence can now be inferred only from a local, abnormal abundance of hornblende or biotite. Between these two extremes many excellent illustrations of partial assimilation may be observed. In nearly all cases the original rock seems to have been one rich in hornblende and biotite and therefore it is assumed that they came originally from the pre-Cambrian.

Relative Ages of the Porphyries

The several types of porphyries are very intimately associated and apparently grade into each other. No definite line of contact was noted anywhere and it is impossible to determine the relative ages except possibly in the case of the Little Bald Mountain sheet. If this porphyry intrusion was the cause of faulting as it appears to be, it is earlier than the intrusions northeast of Halfway, which appear to cover the fault. However, on account of large quantities of talus it was impossible to determine whether the fault was actually covered or whether it merely died out. There are, however, a number of dikes of minor importance which cut both sediments and porphyries and are therefore later.

Age of Deformation and Intrusion

As above mentioned the initial deformation of this part of central Colorado took place in pre-Cambrian time and throughout most of Paleozoic and Mesozoic time there were land masses on both sides of the area under consideration and the site now occupied by the Mosquito Range was submerged and receiving sediments from neighboring land areas. Following the deposition of the Cretaceous formations a great diastrophic movement took place which folded and faulted and raised this area high above the sea. Presumably the porphyries were intruded during this period of deformation but whether during the early or late stages cannot be determined definitely on account of insufficient evidence. Such evidence as is available indicates that at least some of the igneous activity occurred in the early stages. Cases were noted where the porphyry partook of both folding and faulting, but on the other hand the majority of cases show no conclusive evidence that they participated in either folding or faulting.

Contact Metamorphism

The effect of igneous intrusion upon surrounding rocks depends upon a number of factors among which are the size and character of the intrusive, and the character of the country rock which it invades. Other things being equal, subjacent igneous masses produce considerably more metamorphism than the injections. In the Tarryall district, since most of the intrusions belong to the injection type, there has been little of the typical contact effect. It is true, however, that conspicuous changes of varying degrees of intensity may be seen over most of the area. The rock alongside the larger sills shows all stages of change from incipient metamorphism to a complete baking and indurating. The development of new minerals is confined largely to epidote, garnet, specularite, magnetite and actinolite. Accompanying the metamorphism there has been a change of color in the red beds, which are now a dull green, mottled with brown owing to the formation of epidote and garnet. In some places the ferric oxide which gives the red color to the formation has been recrystallized into specularite. Actinolite is often formed in tufts along the bedding planes and in cavities along with epidote.

In most instances these changes are not the result of direct contact with the igneous rock but are more or less uniformly distributed throughout a great thickness of sandstone and shale in such a way as to produce a decided banding. It is thought that the altered bands represent portions of the original rock more susceptible to change by hot solutions and vapors coming from a body of magma at greater depth or that they mark those layers which were more porous and therefore afforded better opportunity for solutions to circulate. In other words, the visible effects represent only the fading out stages of much more intensive changes nearer to the body of magma where the solutions were necessarily more potent.

Great thicknesses of strata have been changed from original argillaceous sandstones and shales to a rock resembling quartzite and hornfels. Concurrently epidote and garnet were formed, producing a hard, dense, brownish-green banded rock, which is very resistent to erosion. In most cases there are no distinct, recognizable crystals of either garnet or epidote but the whole mass is impregnated with very finely disseminated grains of these minerals. Such garnetized and epidotized sedimentary rock is a conspicuous feature of much of the Tarryall formation. As a rule all gradations may be seen from gray-green, hard, siliceous shale to solid masses of garnet-epidote rock. On Mineral Ranch Hill this is accompanied by micaceous specularite, in both the shale and sandstone layers.

Metamorphism of considerable local intensity was observed near the heads of Little French Creek and Montgomery Gulch. Here a heavy garnet zone has been formed containing besides garnet, much magnetite and calcite. This garnet zone occurs along the contact of a calcareous shale with a thick sill of quartz monzonite porphyry. A partial analysis of the garnet shows that it is of the andradite variety. Since all the iron was determined as ferric iron, the result is a little too high. Undoubtedly some is present in ferrous form and this would reduce the total amount as shown in the analysis. No alkali or manganese determinations were made.

Partial Analysis of Garnet from Little French Creek

(A. L. Cairns, analyst)

SiO_2	34.61
Al_2O_3	5.14
Fe_2O_3 / FeO	29.56
CaO	31.72
MgO	0.63
H_2O+	0.13
H_2O-	0.09
	101.88

In texture it varies from granular massive to fine crystalline. The largest crystals observed here were less than three-fourths of an inch in diameter, but these were exceptional and rare. Most of the deposit is fine grained and massive. Under the microscope anomalous double refraction is common.

The magnetite associated with the garnet is also massive. Occasionally octahedral crystals having a maximum size of about a quarter of an inch occur in calcite. In the upper part of Montgomery Gulch a massive magnetite zone about two feet wide has been prospected in a number of places but all were abandoned and only such material as was on the dump could be studied. Assays show that it contains traces of gold and silver.

On the whole, metamorphism such as is found at actual contacts is absent but a large part of the area shows evidence of a thorough soaking or saturation with solutions and vapors given off by a large body of magma at greater depth. If the Princeton batholith underlies this area, as is thought to be the case, it is probably the source from which the solutions came along with the numerous sills.

Economic Geology

The history of mining in the Tarryall district has already been reviewed. As previously stated, most of the old workings have been abandoned for many years, and as nearly all are inaccessible because of caving, very little could be learned from them. In consequence, discussion of economic features must be confined to surface indications, supplemented here and there by such information as may be gathered from the old dumps.

Character of the Ores

Most of the ore observed around the old workings consists of magnetite and pyrite, carrying small amounts of gold and silver. Garnet and epidote are present in much of it, and occasionally a little chalcopyrite is found. On Mineral Ranch Hill, in addition to the minerals mentioned, a ferriferous variety of sphalerite, resembling marmatite, is present in considerable quantity. Native gold in quartz is said to occur in veins, but none was observed. That it does occur, however, is witnessed by the placers along the creek. No record of tonnage or value of ores shipped from the district is available anywhere, hence it is not possible to give any exact figures as to production. Rumors are current that the ore shipped ranged from 15 to 30 dollars per ton. On the other hand, it is also said that some ore was shipped which did not bring sufficient returns to pay the freight.

Mineralogy of the Ore and Gangue

Gold. While no specimens containing native gold were noted, it is quite evident that it occurs in the district, since a considerable quantity has been taken from the placers. Most of the placer gold was in form of fine flakes, more or less angular and in general showing but little effect of transportation. Reports as to the findings of large nuggets are numerous, but none seem to be very authentic. According to the best information available, very few nuggets of any size were found. A careful microscopic study of the magnetite-pyrite ores from veins has not revealed gold, although fire assays prove that it is there.

Sulphides

Pyrite. This mineral is widely distributed in small quantities in some of the porphyries. It was noted in the quartz monzonite porphyry in the vicinity of Halfway, and farther north and northeast in the porphyries that cap the divide between Tarryall and Michigan creeks, and also in some of the sills on Mount Silverheels. It forms an important part of the veins that have been opened up in numerous prospect holes, and is associated in considerable quantity with the contact magnetite deposits. Much of it is massive, but here and there well formed cubes and pentagonal dodecahedrons may be seen.

Chalcopyrite. This sulphide of iron and copper was not noted in any appreciable quantity, but in the ores on Mineral Ranch Hill small irregular grains may be seen mixed with pyrite and sphalerite. Possibly some of the pyrite is copper bearing, as the peacock colored tarnish so common on chalcopyrite is seen on much of the pyrite. Copper has been reported, but only as a negligible constituent, in some of the ores of the district, especially on Mineral Ranch Hill.

Galena. Lead sulphide is present in small quantities and carries a little silver. Not enough galena is present to constitute an ore, although its silver content adds to the value. In every instance noted, it was fine grained and associated with pyrite and quartz. The principal localities where it was seen were in the workings of the Silverheels Tunnel Company, and in an abandoned tunnel on the southeast side of Mineral Ranch Hill.

Sphalerite. This mineral is perhaps the most abundant sulphide noted, especially in the ore from the Illinois Central Consolidated Tunnel on Mineral Ranch Hill. It is found principally as coarsely crystalline aggregates, associated with pyrite, magnetite, and quartz, and as fine grained disseminations in vein matter. Most of it is a black ferriferous variety, with a reddish brown streak, to which the name marmatite is applied. It is said to carry small values in gold and silver, but most of the determinations show that the precious metals are associated chiefly with pyrite and magnetite.

Oxides

Quartz. This is a very common constituent of nearly all the rocks in the district, but in addition to its occurrence as a rock forming mineral, it is also present as a gangue mineral in some veins. It forms an important part of the gangue in a number of veins on the west side of Montgomery Gulch, and is found associated with orthoclase in the Silverheels tunnel, but in most of the other prospects it is conspicuously absent.

As a rock forming mineral, it is abundant. In some of the porphyries, it forms bipyramidal phenocrysts up to three fourths of an inch in length, and in addition shows prism faces ranging in width from the merest line up to an eighth of an inch.

Hematite. Specular hematite is abundant in some of the metamorphosed sedimentary beds. Especially interesting are the occurrences on the west side of Mineral Ranch Hill, where flat rhombohedral crystals of hematite from a quarter of an inch to three quarters of an inch in diameter are found along the bedding planes of metamorphosed shales. Micaceous varieties are also common in some of the sandstones, and are associated with epidote, garnet and calcite.

Magnetite. Magnetite occurs abundantly in veins and metamorphosed sediments, intimately associated with garnet, epidote, calcite, and pyrite. It is the principal constituent of most of the ores, and can be found in considerable quantities on the dumps, at many of the tunnels and prospect holes. At some of the old mill sites many tons of ore, chiefly magnetite, can still be seen. According to reports most of the values in gold and silver were found in magnetite.

As a general rule it occurs massive with but little tendency towards crystalline structure, but in the workings at the head of Little French Gulch and in the neighborhood of the Baxter Mine at the head of Montgomery Gulch, distinct octahedrons a quarter of an inch in diameter are found associated with calcite and garnet.

Boulders and nuggets of magnetite are found abundantly in the gravel along the creek. These undoubtedly came from veins outcropping higher up on the mountain sides and were brought down to their present position by the streams and by the glaciers. Black sand, which is largely magnetite, is also very abundant and may be seen along the streams, even out on the plains of South Park.

Limonite. This mineral, which is one of the common products of oxidation of any mineral containing iron is everywhere present in the oxidized zone and needs no special mention.

Carbonates

Carbonates, except calcite, are rare. Small amounts of azurite and malachite were seen as stains on ore minerals, and small amounts of oxidized siderite were noted. Calcite is of widespread occurrences, having been formed during metaphorism of the sediments. Intimately associated with it are garnet and epidote. Usually it is massive, but always shows its usual cleavage. In some of the epidotized rocks, it is green, due to included epidote, and except for its cleavage might easily be mistaken for that mineral.

Silicates

Only a few of the silicates need special mention here, as they have already been described in the section on petrography.

Garnet. Garnet formed during metamorphism of the sediments, is so abundant that it deserves special mention. It is present in small quantities near all of the igneous intrusions, but a particularly heavy garnet zone has been developed near the head of Little French Gulch. From here it extends northward and southward parallel to the strike of the beds, and can be seen in a number of places along the mountain sides. It has been considerably prospected, but, judging from the character of the workings, proved valueless. In the material thrown out on the dumps, magnetite, epidote, and a little quartz were intimately associated with the garnet. Most of it is massive or granular, but occasionally crystalline masses and well-formed individual crystals were found. Under the microscope, between crossed nicols, it frequently shows anomalous double refraction in zones parallel to the trapezohedral faces. A chemical analysis shows that it is probably the variety andradite. (See analysis on page 55).

Epidote. Epidote is perhaps the most widely distributed silicate, exclusive of those which occur as primary minerals in the igneous rocks. It has been abundantly developed by metamorphism in the red sandstones and shales, and as a result of its widespread dissemination, it has given a decidedly greenish color to the rocks. Wherever the development of garnet and epidote has been noted, it has been accompanied by a loss of the red color of the sediments.

Orthoclase. This feldspar was found in large masses with graphic intergrowths of quartz, on the dump of the Silverheels tunnel but as the workings had caved, nothing could be learned of its occurrence. In appearance it resembles that found in pegmatite dikes.

Types of Deposits

Since the old workings are at present inaccessible, very little could be learned as to the real character of the ores or the types of deposits represented. Such material as was found on the dumps at various prospects indicates two principal types, (1) deposits related to contact action showing replacements of country rock along bedding planes; and (2) fissure fillings with a quartz gangue. Both types of deposits are found in the area around the headwater of Middle Tarryall Creek, which has been the center of nearly all the active prospecting in the district. In addition to these types, mention must also be made of the placers along the streams.

Deposits Related to Contact Action

Under this heading will be included those deposits which though not formed directly at the contact of igneous intrusions with surrounding rock are nevertheless thought to have been formed as the result of solutions and vapors given off by the magma.

This type of deposit was noted on Mineral Ranch Hill where the Illinois Central Consolidated Mining and Milling Company has driven a tunnel nearly 1500 feet long to explore it. The ore body said to have been cut by the tunnel is at present inaccessible because of caving but material thrown out on the dump showed replacement of calcareous shales and sandstones and thin limestones as well as porphyry by pyrite and sphalerite. Garnet, epidote, magnetite and specularite are associated with the ore in varying quantities. The ores carry a little gold and silver and traces of copper. The sphalerite is dark brown to black and is probably the ferriferous variety known as marmatite. It varies in texture from fine crystalline to massive and is rather intimately associated with pyrite. Evidence that the ore bearing solutions entered along bedding planes and other lines of weakness is seen in the much greater percentage of ore minerals near such lines of weakness than elsewhere. There is no sharp line of contact between the ores and the wall rock but a gradual decrease in the amount of ore may be seen away from the channel of access.

Many other small deposits that belong to this type were observed but most of them carried no sphalerite. The most common constituent is magnetite which carries small quantities of gold. Shipments of this ore are said to have run from 20 to 30 dollars in gold per ton with a little silver. Reports of richer ore in some of the workings are current but could not be verified.

Many attempts were made in the past to mill and concentrate the ore. The results of the various projects can be judged from the many abandoned mills and stamps which give silent testimony in the form of ruins. At one time a smelter was built in Montgomery Gulch in an attempt to recover the valuable metal from the ores and concentrates at the mine to avoid heavy freight charges, but it too resulted in failure.

Fissure Veins

Along with the deposits just described are some which are termed fissure veins because as a rule they represent a different type of deposit. They carry none of the minerals of contact origin noted in the preceding type but on the other hand they consist mainly of quartz and pyrite. All of those observed were narrow and probably represent fissure fillings as there was no evidence of replacement of wall rock. Apparently they are later than the contact-replacement type described, since they cut across these. No actual cases could be studied but the information obtained from specimens on the dump showed that there was no replacement effect at the crossing. In all the cases observed there was a sharp clean break, which had subsequently been filled with quartz.

These quartz veins are said to carry small amounts of free gold and they are looked upon as the sources from which the placer gold was derived. As a result they have been persistently followed but as yet the hopes of the prospectors have not been rewarded with success. Either the richer parts of the veins have been entirely removed by erosion or else the real source of the gold has not yet been found.

Gold Placers

The most productive placer workings were the Fortune, Roberts and Peabody claims in the lower part of Tarryall Gulch and the Mineral Ranch Hill and Liebelt placers on Little French Creek. The material of these placers consists very largely of stream worn sand and gravel together with glacial debris. The sedimentary series with interbedded sills forms the bed rock on which the gravel rests. As these beds dip down-stream they form natural riffles behind which the gold particles collect.

Very little could be learned as to the amount of gold recovered from these gravels or as to yield per yard. All work has ceased and only the abandoned sluices and pipe lines bear witness to the activities of former days.

The earliest means of exploitation was with shovel and pan, and later the rocker was added, to lessen the labor and increase the output. Drifting in the gravel just above the bedrock floor was resorted to in all the important placers and later, the Fortune Placers Gold Mining Company introduced hydraulic washing. For a number of years they operated with varying success but in 1917 the cost became too great and work was abandoned. Meanwhile the ranchers of South Park had an injunction served on the company restraining them from further work, because the silt and sand washed downstream clogged their irrigation ditches.

Prospecting for placer ground has very largely been carried on by means of pits but no systematic attempts have ever been made. A large part of the valley above the Fortune Placers offers an excellent opportunity for prospecting and may prove to be rich enough to permit exploitation. Similarly a large area at the mouth of Tarryall Gulch, where the Creek flows out on the plains of South Park will bear further prospecting. This is so situated that it can be handled with a dredge, provided the gravel contains sufficient gold to warrant such an installation.

Genesis

Such ores as occur in this district are very largely associated with rocks in which epidote, garnet, magnetite and specularite have been formed. These minerals are very commonly of contact metamorphic origin, even though they may not always occur directly at the contact. As has already been pointed out, in spite of the fact that no very intense changes are found in rocks at the contact with the porhyry sills, there has nevertheless been a great amount of change brought about in the sedimentary rocks, by solutions or gases of magmatic origin which permeated and penetrated a great thickness of strata. This change is manifested by the formation of garnet, epidote, magnetite, specularite and other minerals. Since the same set of minerals are found associated with the sulphides it is entirely reasonable to assume that all came from the same source. Moreover, they are very intimately associated in a way that suggests contemporaneous deposition or possibly overlapping periods of deposition. Silicates and oxides were deposited first, followed by sulphides and these in turn followed by more sulphides.

It does not appear likely that the metamorphic changes in the country rock of the Tarryall district can all be attributed to the quartz monzonite porphyry sills but rather that some of the changes resulted from the escaping materials from a large batholith which is thought to underlie the area. If this is true it also probably is true that the ore bearing solutions came from the same batholith at the same time. In fact it is impossible to draw a line between the formation of metamorphic minerals and ores. The conclusion that these ores were deposited from solutions rising from a deep lying batholith is therefore strengthened, and although they are not contact metamorphic deposits, strictly speaking, they partake of some contact action.

The ore in the veins probably came from the same source at a slightly later period, perhaps during the final stages of solidification of the batholith. The fissures are not thought to be related to major faulting as no great displacement is apparent.

The time of mineralization can not be determined from the limited area studied. Undoubtedly it occurred after the intrusions of quartz monzonite porphyry had taken place but whether it occurred before or after the folding and uplift cannot be determined definitely. There is no evidence to show conclusively whether the porphyry sills participated in the folding or whether they were intruded afterwards.

Future development

If the origin of the ore deposits has been correctly interpreted and if a great batholith underlies the area and furnished the solutions which deposited the ores, there is no great probability of encountering deposits of valuable ore at lower depth. In accordance with the recognized zonal distribution of the metals around intrusive rock bodies, sulphides of copper and zinc are among the first to be deposited and occupy positions nearest to the intrusive. Above and beyond these would come lead and silver ores and still farther out from the intrusive one would expect silver and gold ores. If this distribution holds true it can be seen that the deposits above described belong to the first zone and therefore it does not appear likely that very large or valuable deposits will be found at depth even though the limestones which are heavily mineralized at Leadville and Alma, dip eastward and are found under the younger strata in the Tarryall district.

The future of the Tarryall district probably lies in more systematic prospecting of the gold placers. There is still a considerable amount of placer ground which might be handled by improved methods and up-to-date equipment.

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