COLORADO STATE GEOLOGICAL SURVEY
BOULDER
R. D. GEORGE, State Geologist

BULLETIN 9

GEOLOGY AND ORE DEPOSITS

OF THE

BONANZA DISTRICT

SAGUACHE COUNTY
COLORADO

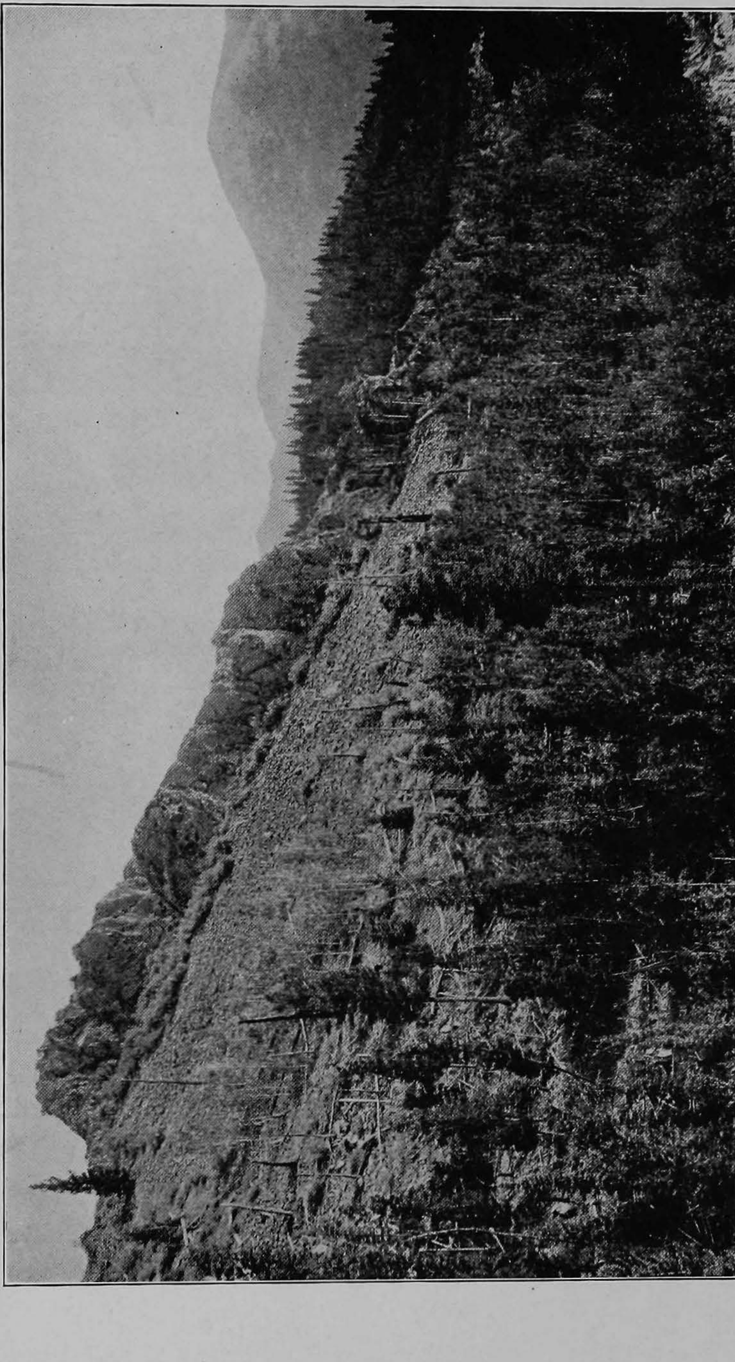
By

HORACE B. PATTON

1915

DENVER, COLORADO
EAMES BROTHERS, STATE PRINTERS
1916

DOI: https://doi.org/10.58783/cgs.b09.vtso7767



Outrop of Bonanza latite, mouth of Elkhorn Gulch. The marked bedding is due to flow structure

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LETTER OF TRANSMITTAL

STATE GEOLOGICAL SURVEY,
UNIVERSITY OF COLORADO, December 2, 1916.

Governor George A. Carlson, Chairman, and Members of the Advisory Board of the State Geological Survey.

GENTLEMEN: I have the honor to transmit herewith Bulletin 9 of the Colorado Geological Survey.

Very respectfully,
R. D. GEORGE,
State Geologist.

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Geology and Ore Deposits of the Bonanza District, Saguache County, Colorado

CHAPTER I

INTRODUCTION

EARLY HISTORY

The mining town of Bonanza furnishes an admirable example of that astonishing mushroom growth that has characterized the founding of so many mining camps in the Cordilleran west. Not only in its sudden growth from nothing to a populous mining community, but in its almost equally rapid decline after its failure to live up to the early expectations of limitless wealth has Bonanza many parallels in the Rocky Mountain mining districts. That, however, the town as a mining camp has persisted and today is able to show no little interest in the development of its mining resources, may be attributed to the fact that such resources do exist, and that those interested in their development have not lost faith in their ultimate success.

Soon after the great excitement created by the discovery of rich silver deposits at Leadville prospectors, scouring the mountains in the surrounding districts, succeeded in 1880 in uncovering rich gold and silver veins in the so-called Kerber Creek district of Saguache County, and the town of Bonanza suddenly sprang into existence. Its population during the first one or two years is not definitely known, but it has been variously estimated at from one thousand to one thousand five hundred. Population in those days and in mining camps of this character was customarily estimated not by the methods of a census taker, but by counting the number of saloons and dance halls. While the actual number of inhabitants is not known, it is a matter of record that at one time Bonanza was the proud possessor of thirty-six saloons and of seven dance halls. An old photograph, taken in 1881, is reproduced in Plate 4, Fig. 1, and gives a fair idea of the activity of the camp one year after the first discovery of the precious metals in the district.

The first discovery of mineral is said to have been made in 1880 by Tom Cooke of Salida, who came over the range looking for horses and stumbled across rich ''float'' in Copper gulch. The first mine opened was the White Iron, a claim that was quickly abandoned after taking out a small amount of iron sulphide (said to be marcasite). Following the location of the White Iron came the Cornucopia, Bonanza, Rawley, and Revenue. Of these the Bonanza made the best showing, yielding, it is said, from the ''grass roots'' an ore that ran two hundred dollars to the ton. A small smeltery was erected above the town, the treatment charges being forty-five dollars a ton.

By 1882, or only two years after the first discovery of ore, it became evident that the high grade values necessary for profitable mining under the existing conditions did not exist, or, at least, were not likely to be found to any great extent, and the camp quickly lost its population. In spite, however, of the great drawback imposed by remoteness of location and by lack of transportation facilities, prospecting and development have been carried on more or less continuously to the present time. As will appear later, pending the extension of suitable transportation facilities, no great attempt has been made to develop the more extensive ore bodies now known to exist in the district.

LOCATION

The town of Bonanza is situated on the north branch of Kerber creek. It is about fifteen miles north of Saguache, the county seat of Saguache county, and twenty miles southwest of Salida. The nearest station of the railroad is Villa Grove, distant sixteen miles by wagon road and located in the upper end of the San Luis valley on the Alamosa branch of the Rio Grande railroad. From Villa Grove a fairly good county road, over which an automobile stage line is operated, runs to Bonanza, connecting with the two daily trains from Denver and Salida.

The area embraced in this survey covers a total of some seventeen or eighteen square miles. It lies almost entirely east of the north branch of Kerber creek. Its eastern boundary follows the high ridge or range that runs northerly from Hayden's Peak and connects with the Cochetopa Hills that lie to the north and north-

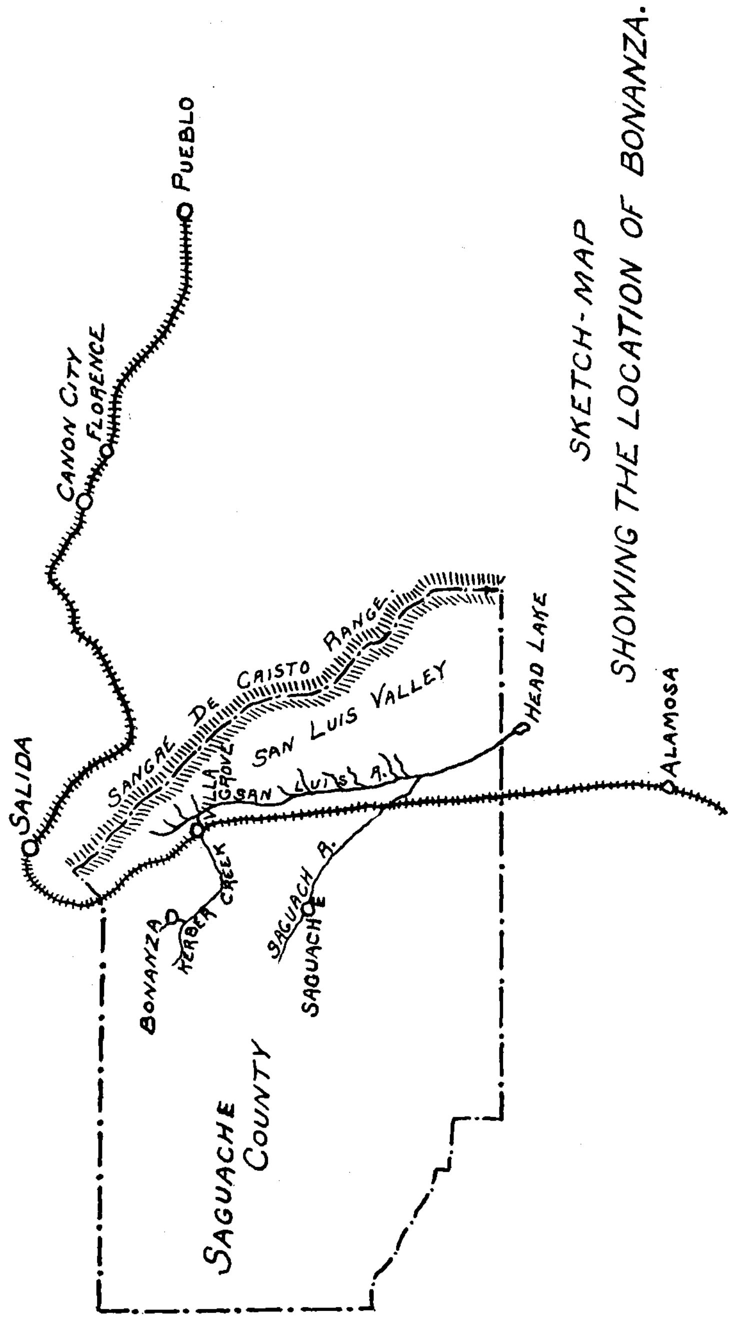

SKETCH-MAP
SHOWING THE LOCATION OF BONANZA.
PUEBLO
CANON CITY
FLORENCE
SALIDA
SANGRE DE CRISTO RANGE.
SAN LUIS VALLEY
VILLA GROVE
SAN LUIS R.
HEAD LAKE
ALAMOSA
SAGUACH R.
SAGUACHE
KERBER CREEK
BONANZA
SAGUACHE
COUNTY

Fig. 1

west of the Kerber creek valley. Within this area will be found practically all the mining properties of any consequence, as well as most of the prospects in the Bonanza district.

TOPOGRAPHY AND GEOGRAPHY

While there are no mountain peaks of very great elevation above the sea, the highest being only a little over twelve thousand feet, the area under consideration is upon the whole extremely mountainous, in that there are no level stretches of consequence and in that the mountain slopes are everywhere exceedingly steep. The lowest elevation to be found on the map is nine thousand feet, which gives a difference of three thousand feet in elevation between the lowest and the highest points. On the extreme southeast corner of the area surveyed is located Hayden's Peak with an elevation of 11,979 feet. This peak furnishes one of the important triangulation stations in connection the United States Geological and Geographical Surveys of the Territories, conducted under the direction of E. V. Hayden and more popularly known as the Hayden Survey. This peak when seen from the east and south has a marked pyramidal shape and forms a most conspicuous feature when viewed from any point in the upper part of the San Luis Park. It is in fact a very prominent summit and dominates the landscape for the traveler along the county road leading from Villa Grove up the Kerber creek valley towards Bonanza.

From this peak northward runs a mountain ridge fairly continuous for about three and a half miles and then for a similar distance northwestward to the northwest corner of the mapped area. This ridge which forms the eastern and northern boundary of the map is surmounted by a succession of more or less marked summits, some six or eight in number, that rise several hundred feet above the general average of the ridge, some being a little higher than Hayden's Peak and some lower (See Plate V, Fig. 1 and Fig. 2). On the extreme north lies a whitish topped conspicuous peak that locally goes under the name of Porphyry Peak, so called from the porphyry, or, as the author prefers to call it, the rhyolite that forms the summit.

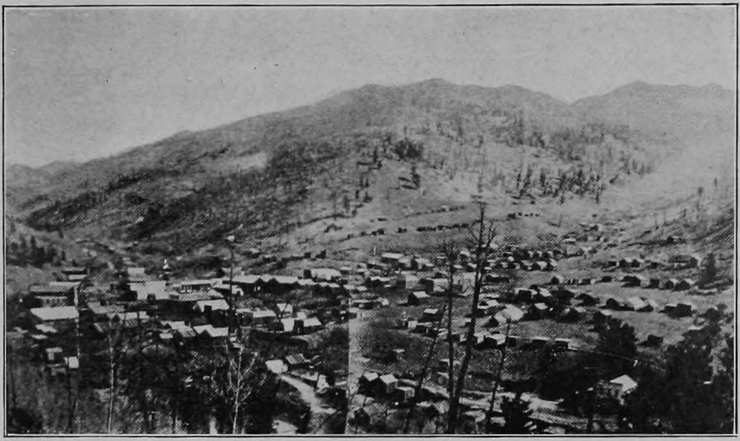
Kerber creek and its main tributary, Squirrel gulch creek, flow in a general southerly direction from the source on Porphyry Peak to the southern edge of the mapped area (see Plate VII, opposite page 16). All the area to the east of this main valley is drained by a series of markedly parallel streams that rise near the summit of the above described ridge and run southwest through deeply cut and very steep-sided valleys. These lateral valleys are spaced about a mile apart. Beginning with the south they are in succession Eagle Gulch, Elkhorn Gulch, Copper Gulch, Rawley Gulch, and Bear Gulch. Between the two last named gulches a much shorter gulch is to be seen with parallel course.

All the area lies below the so-called timber line except that the higher summits are bare or practically bare of timber. With these exceptions and with the further exception of a very small strip lying along the lower Kerber creek the entire district is well wooded, in part heavily wooded, except where the timber may have been cut for lumber or fuel or for mine timbers.

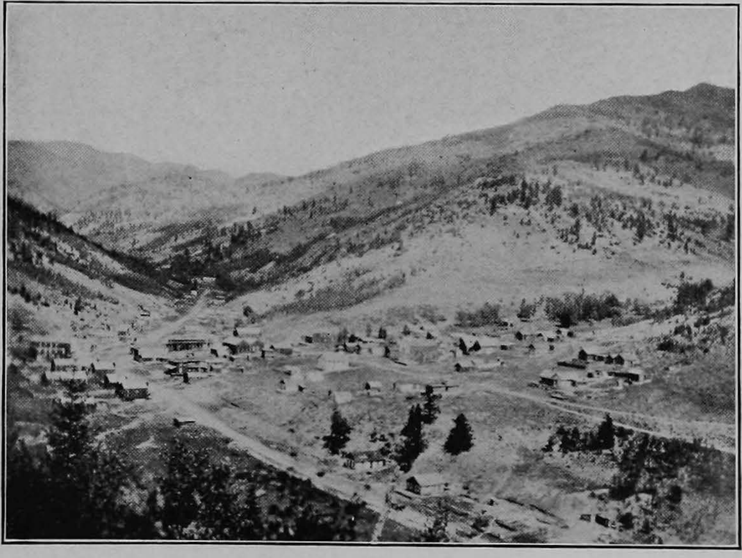
The mountain sides are for the most part heavily covered with soil so that actual rock outcrops are not extremely abundant. As will be seen later, the heavy soil and the thick tree growth that characterize nearly all of the district under consideration have made it difficult if not impossible to map the geologic formations with great exactness. The heavy growth of vegetation is undoubtedly due to the fact that the district is well watered. The winter precipitation of snow is doubtless heavy, as snow drifts persist in sheltered places well through the summer months, and all the larger creeks tributary to the Kerber were found to be flowing at the close of August.

Most of the district is made fairly accessible by means of roads. As already stated, the county road from Villa Grove runs up the Kerber creek valley to Bonanza. Above the town a road in fairly good condition runs up the Kerber valley for two or more miles beyond the junction with Squirrel Gulch, and another good road runs up this latter valley to the saw mill, a distance of about two miles. This last road was formerly part of a toll road that followed up to near the head of Squirrel Gulch, then turned sharply to the left and circled around the west side of Porphyry Peak, and descended on the north side towards Poncha Pass and Salida. This road is no longer accessible for wagons after it leaves the valley.

Another main road, kept open in the summer time, leads up Rawley Gulch to the Rawley mine, from which point it climbs out of the valley to the north and crosses the main ridge just south of Round Mountain and descends on the east side into the San Luis valley. Other fairly accessible roads run a mile or two up Copper and Elkhorn gulches.



A. Bonanza, looking north. From a photograph taken in 1881.



B. Bonanza, looking north. From a photograph taken in 1912.

Numerous other roads built for mining or logging purposes are available to a greater or less extent, at least for horseback riding.

ORGANIZATION

By arrangement with the State Geological Survey the work described in this report was undertaken by the Geological department of the Colorado School of Mines under the direction of the author, who is responsible for the geology, and in part for the topographic mapping. The latter work was done mainly under the direction of Professor G. M. Butler, with the assistance of Mr. Roy F. Smith, who at the time held the position of assistant in the department. To a very great extent the actual field work involved in the preparation of the topographic map and to some extent the work involved in the geologic mapping was done by a class of eight student members of the Senior class. The following students participated in this work: Arthur C. Bigley, C. J. Daman, Daniel B. Gregg, Chich Ho, Waller C. Hudson, Rastus S. Ransom Jr., Frank M. Stephens, and Shoa-Ying Wang.

So far as the topographic and triangulation work is concerned, it has been found that the student members of a party like this, because of a certain degree of practice in methods of work already attained in connection with their school curriculum, can, under careful supervision, be trusted to do fairly reliable work. In geologic mapping and observation, however, a much more constant direction and assistance is necessary. So far as possible, therefore, the author has personally gone over the ground either independently or in company with the students assigned to this work.

The field work was done during eight weeks in the summer of 1912, supplemented by a further week on the part of the author in the summer of 1914.

ACCURACY OF WORK

As already stated, the heavy growth of vegetation, coupled with a nearly universal thick covering of soil, has rendered geological mapping rather difficult. Undoubtedly these difficulties are no greater in this field than the geologist usually encounters, and, with sufficient time at one's disposal, accurate mapping would be entirely feasible. In this case, however, owing to the character of the rock formations, more especially owing to the extensive alteration to which nearly all the rocks have been subjected, it was found to be unusually difficult to draw sharp lines of demarkation between the formations. To have done so would have involved long and repeated microscopic investigations and repeated field studies. To a certain extent it was found necessary to prepare and study while in the field thin sections of some of the rocks in order properly to classify and map them. The author does not lay claim, therefore, to a great degree of accuracy over most of the territory, and especially can he not claim more than approximate accuracy in those parts of the area surveyed that are remote from the located mining claims. Probably this lack of exactness in the geologic mapping can have but little or no significance in so far as the geology is related to the ore deposits as, with the exception of the acidic rhyolites in the northern and northwestern part of the area, where there are no known ore deposits, the chemical and mineralogical differences in the rock types are not marked.

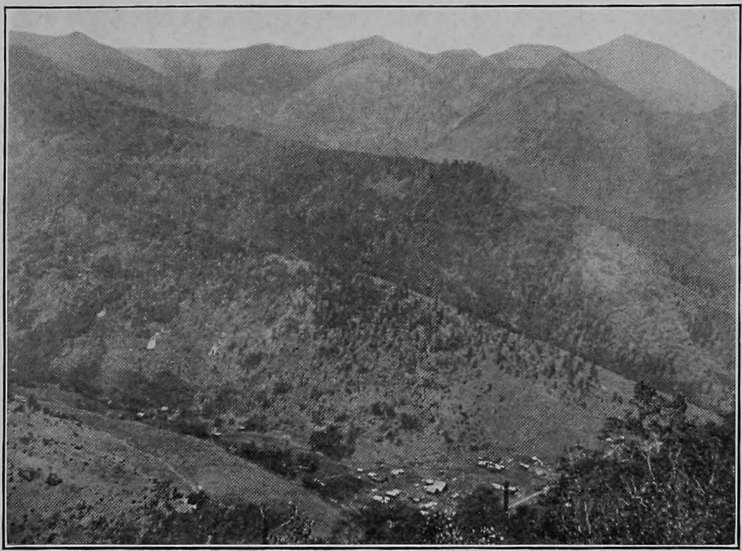
DESCRIPTION OF MAPS

The map showing the topography and geology of the district is to be found on Plate I (in the pocket). It is made on a scale of 2,000 feet to the inch. The interval between contours is 100 feet. In connection with the triangulation work it was found necessary to establish stations on various summits and conspicuous points, for which no local names appear to have been given. The more important of these triangulation stations have been indicated on the map by a triangle and marked by the letter T followed by a number. In the absence of proper names these numbered triangulation stations may serve a useful purpose in identifying localities. For each of these stations the exact elevation is given.

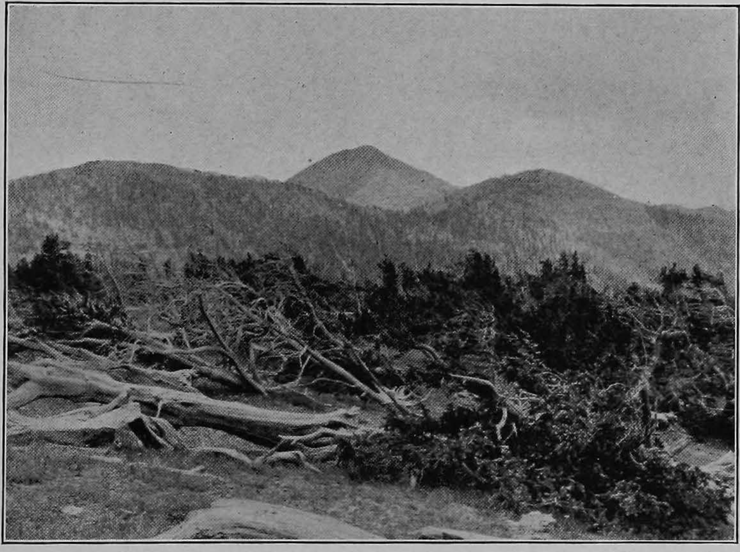
The mining claim map (Plate II, in pocket) has been prepared from the records and charts at the Surveyor General's office in Denver. It includes patented claims of record down to March, 1915, and a few additional unpatented claims. Lists of these claims tabulated by number and by alphabetical arrangement will be found on pages — and —.

ACKNOWLEDGMENTS

To many of those interested in the development of the Bonanza district and to those owning or managing the various properties the author is under great obligation for numerous courtesies



A. Bonanza, looking southeast, with Hayden's Peak in the distance to the right.



B. Hayden's Peak, in the middle distance, as seen from East Porphyry Peak.

extended. To Will C. Russell, the manager of the Rawley Mining Company at the time the investigation was made; to Mr. Charles E. Beckwith, at present manager, and to Messrs. Simonds and Burns, consulting engineers of the same company, special thanks are due for hospitality shown, for opportunity to make a study of the mine and tunnel and for valuable information concerning the property and the ore values. Much of the information obtained as to the development of the Bonanza mine and as to the milling of the Bonanza ore is due to the kindly assistance of Manager W. P. Cary. A similar debt is gratefully acknowledged for valuable information concerning other properties received from J. P. Poole, Dan Mahoney, John E. Ashley, Frank W. Leavitt, W. J. Bennett, D. I. Whiteman, and L. W. Sharpe. To Mr. Augustus Locke of the Geophysical laboratory of the Carnegie Institute at Washington the writer is under obligation for an examination of several of the ores of the Rawley mine.

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CHAPTER II

TOPOGRAPHIC FIELD-WORK

TRIANGULATION SURVEY

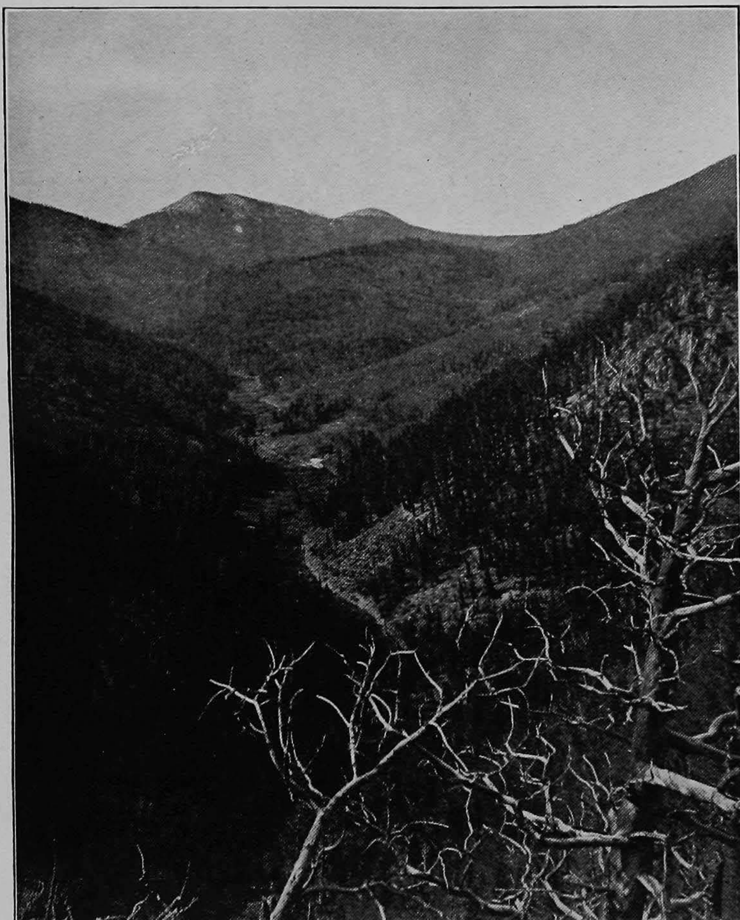
EXPLANATORY NOTE

Owing to the accidental destruction of one of the original note books, full details of the triangulation survey of this district cannot be presented, but, as comparatively few are likely to be interested in such details of the survey, their omission from this report will not detract from its usefulness. However, it may be well to present briefly some of the more important features involved in a triangulation survey and the particular conditions to be met in this case.

BENCH MARK

In order to conduct a triangulation survey it becomes necessary to tie such triangulation to some already established bench mark, that is, to a point whose elevation has been definitely established. The nearest bench mark available was that of the elevation of the tracks of the Denver and Rio Grande Railroad at Villa Grove. This was taken to be 7,958 feet above sea level. This elevation differs slightly from that commonly accepted by the Denver and Rio Grande Railroad, as the Villa Grove elevation was originally determined by leveling from the Union Station at Denver, and more recent leveling by the United States Geological Survey has shown the formerly accepted level of the Denver Union Station to be slightly in error.

Inasmuch as this elevation at Villa Grove cannot be relied upon as final and may be subject at no very distant date to a correction of unknown amount, it was not thought advisable to run a line of levels over the sixteen miles of road that separate Villa Grove from Bonanza in order to establish a bench mark at the latter place. For the purpose in view it was thought sufficient to determine the elevation by means of an unusually reliable



View looking up Squirrel Gulch, showing East and West Porphyry Peaks at the head of the valley.

aneriod barometer which the party was fortunate enough to possess. Three independent readings were made between Villa Grove and Bonanza by means of this aneroid, the intervals of time elapsing between the readings being not over an hour and a half. As the weather conditions were very stable and the readings checked within five or ten feet, the average of the three readings was taken as a satisfactory bench mark elevation. This bench mark was established for a point opposite the camping place of the party in Rawley gulch about a mile and a half above Bonanza.

BASE LINE

In establishing a base line as the foundation for a triangulation survey it is desirable to secure a long level tract, free from obstructions, centrally located and within sight of the most important; or, at least, the most conspicuous points of the district to be surveyed. Such an open and level tract, however, was not to be found. The valley bottom of the Kerber creek is not straight for any considerable distance and the valley is so narrow and the valley walls so steep that but little can be seen from the ends of a base line located along the valley. The only open ground proved to be located along the crest of the ridge or range on the extreme east side of the area to be surveyed. While no level ground could be found, a base line was finally located that had the advantage of being straight, nearly all of it on open ground free from timber, a little over a mile in length, and each end visible from the other end.

This base line starts from the summit of Round Mountain (see Plate VIII, Fig. A, opposite page 18) on the north and runs for a distance of 5,702.15 feet to the southeast, to the summit of an elevation at the head of Rawley gulch. The northern end of the base line is designated on the map by the letters NBL, the southern end by the letters SBL. This base was very carefully measured by means of steel tape and subsequently checked very closely by two independent traverses. Its bearing was established by solar observations and by reading on polaris, the two methods agreeing to the minute of arc. The bearing as determined by solar observation was S. 37° 20′ E. from NBL on Round Mountain. In measuring the base line a straight traverse was run in which the two ends of the base line were not always visible. This traverse deviated only one minute from the bearing above given for the base line as determined by solar observation.

This base line was upon the whole quite favorably located, as a large number of prominent points could be seen from both ends of the line and hence it was possible to determine accurately the location of these points.

TRIANGULATION

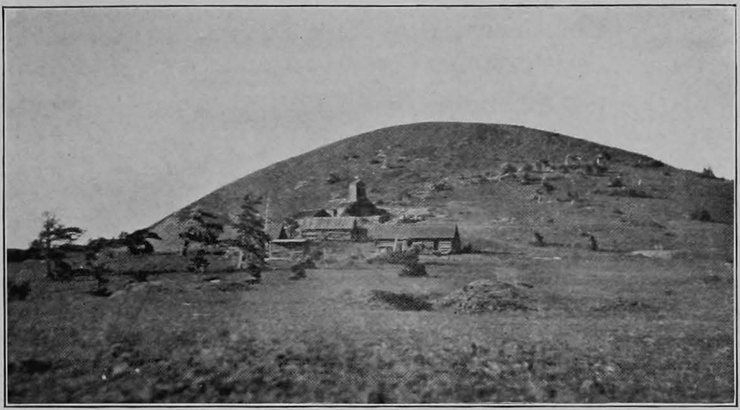
Having once determined accurately the length and the bearing of the base line, as well as the relative elevations of the two ends, it was possible to make a triangulation survey of the district, starting from the two ends of the base line. Flags were placed on all prominent points visible from the base line, such as mountain peaks, lone trees, conspicuous rocky crags, the gables of mine buildings, etc. From each end of the base line the angles were carefully read between the direction of the base line and the lines of sight of these prominent points. Wherever possible the objects were located by intersection of these lines of sight and checked by intersections of lines of sight taken from other well established points. In this transit work the horizontal angles, that is, the angles between lines of sight measured in a horizontal plane were customarily repeated six times and the average of the six readings taken. At the same time vertical angles were read giving the deviation from a horizontal plane of the lines of sight. These vertical angles were read both direct and reversed and the average taken. Most of the transit work in connection with the primary triangulation and in the running of the base line was done by Mr. R. F. Smith.

After establishing primary points by means of the triangulation survey, a secondary triangulation was readily carried forward by making use of the calculated distances as known sides of the triangle, and thus the triangulation was carried to parts of the territory not visible from the original base line.

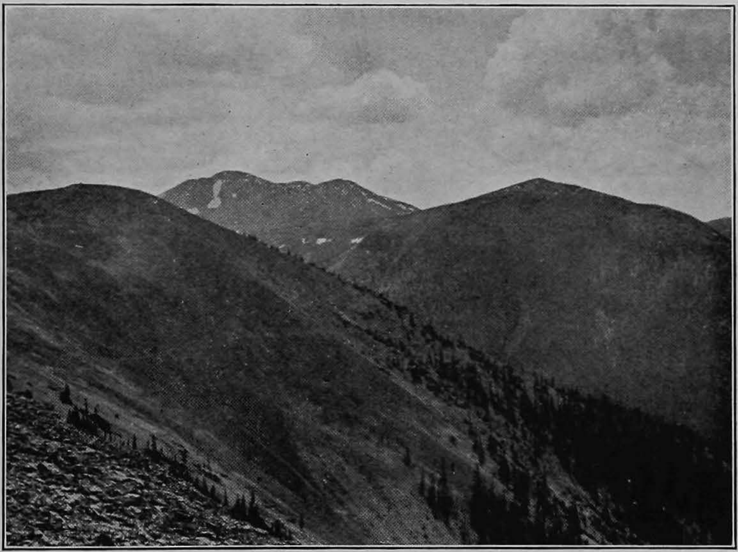
METHODS OF CONTOURING

SPECIAL METHODS REQUIRED

Methods that ordinarily would have been used in contouring a region of this character were not available without considerable modification because of the character of the party in the field. As already stated, most of this work was done by the student members of the party. While in a general way they had already had some experience in contouring in connection with the regular



A. Round Mountain and the Shawmut Mine.



B. West Porphyry Peak with Mount Antoro in the distance.

course in surveying, their experience was not such as to enable them to undertake the mapping of a large area except by the expenditure of more time than could be devoted to this work. Furthermore, it was necessary to divide the territory to be covered into four subdivisions, with two assigned to each subdivision. In a way, therefore, it was necessary to carry on four independent parties and yet have their work agree with each other. Also because of lack of experience on the part of the workers it was necessary to have frequent checks on the work so as to avoid considerable errors.

TRAVERSES

One of the methods for establishing such checks involved the running of frequent traverses. As far as possible this was done with a steel tape; in other cases a stadia traverse was considered sufficient. Such traverses were run up all the main valleys and gulches, or along some of the main roads. As roads are to be found along all of the principal gulches, the running of such traverses became an easy matter and enabled the party to map the roads with great accuracy.

Such a traverse was run the entire length of the Kerber creek valley within the confines of the mapped area. Other traverses were run practically to the head of Eagle Gulch, Elkhorn Gulch, Copper Gulch, Rawley Gulch, and Squirrel Gulch. The Rawley Gulch traverse was continued to the crest of the range and was tied onto the south end of the base line. Another traverse followed the county road from the Rawley mine in Rawley Gulch up to Round Mountain and tied on to the north end of the base line.

By means of these traverses the main lines of drainage and the main roads were accurately located. Furthermore, there were but few points on the map that were distant much more than half a mile from some traverse, and, in these cases, a triangulated point was available for purposes of location.

In running these traverses a stake was set at each station, such stakes being numbered consecutively, and the measured distances as well as the horizontal and vertical angle readings of the transit recorded. From these data the elevation of each stake was figured out and recorded in each field note book. A student, therefore, having this information constantly at hand, was always in position to establish the correct position of the contours wherever they crossed the traverse lines. By this means also the contouring work done in two contiguous tracts was easily made to conform, as the traverses were made the division lines wherever possible.

With these traverses established and the position of the contours known wherever they crossed the traverse lines, and with the additional aid of the numerous triangulated points, it was no very difficult matter to prepare a fairly accurate contour map of the entire area.

USE OF PLANE TABLE

Both in the contouring and in the location of prominent positions, such as houses, tunnel mouths, shafts, mine buildings, conspicuous outcrops, etc., plane tables were constantly used. These consisted of a plain wooden board either sixteen by sixteen inches or twelve by sixteen inches square, mounted on an ordinary camera tripod. A simple alidade without telescope attachment was found to be quite accurate enough for the purpose. In most cases, in lieu of an alidade a Lietz mining clinometer was used, set on edge. This clinometer includes a compass and hand level, measures approximately six by three inches, and is half an inch thick. By sighting along one side a line of sight can be established almost as readily and accurately as with an alidade. At least this is true for short sights of not over half a mile.

OTHER INSTRUMENTS USED

Where elevations could not be obtained directly from triangulation or traverse stations, the hand level and the aneroid barometer were used. For open ground the hand level was given the preference as being more reliable, but in heavily wooded areas hand leveling was too difficult and reliance was placed on the aneroid. On account of the many stations established by triangulation and by traverses it was usually easy to keep a fairly good check on the barometer, so that changes of air pressure due to fluctuation of weather conditions did not materially interfere with the work.

CHAPTER III

GEOLOGY AND PETROGRAPHY

DESCRIPTION OF THE ROCKS

PRELIMINARY

The Bonanza district is situated near the northeastern edge of an extensive area of igneous rocks that may be conveniently designated the San Juan igneous district. This area extends practically unbroken from the heart of the San Juan mountains in San Juan and Ouray Counties towards the southeast through Hinsdale, Mineral, Rio Grande, and Conejos Counties to and beyond the New Mexico boundary, and towards the northeast through Hinsdale and Saguache Counties to Poncha Pass at the northern end of the San Luis valley.

The rocks of this extensive igneous area are mostly of tertiary age and are prevailingly of the andesite and latite types and their intrusive and plutonic equivalents. The more acidic and basic types represented by the rhyolites and basalts are also extensively developed, as are their coarse grained and deep seated equivalents. On the northeastern edge of this igneous area, at Bonanza, the rocks are all, with very trifling exceptions, extrusives, that is, surface lava flows. At least, within the area covered by this report, none of the intrusive or plutonic equivalents are disclosed. All other rock types represent portions of the Precambrian floor on which the volcanic series was poured out.

Beyond the borders of the Bonanza district on the east the volcanic series is seen to lie upon Carboniferous and upon Precambrian rocks. The Carboniferous doubtless occupies relatively small and isolated areas lying directly on the Precambrian metamorphic rocks. Both Precambrian and Carboniferous rocks are to be seen on the road between Villa Grove and Bonanza on both sides of Kerber creek, beginning at a point about eight miles below Bonanza and continuing down to the San Luis valley. Along the creek bottom they are covered by alluvial wash

Within the area covered by the Bonanza map no Carboniferous rocks were met with. Two or three extremely small masses of Precambrian rocks were found that probably are fragments picked up by the igneous magma as it broke through the older formation. In the extreme northern part of the map is a somewhat larger mass of crystalline rocks that are more likely part of the Precambrian floor on which the lavas rest. This mass has been exposed through the erosion of the overlying igneous rocks.

IGNEOUS ROCKS

Introductory

The igneous rocks of the Bonanza district, except the few insignificant occurrences that belong to the Precambrian formation, may be grouped under three types designated respectively as rhyolite, latite, and andesite. All three types occur in this district as surface flows or in small dikes that were probably originally connected with surface flows. In the case of the andesite and rhyolite there is abundant evidence that tuffs and breccias as well as lava flows abound in the district. This is apparently not true of the latite.

With the exception of a few very small dikes the rhyolite is confined to the northeastern portion of the territory covered by the Bonanza map. This rhyolite body is entirely outside of the ore-bearing area of the district. The rock seems to be free, or nearly free, from mineralization by sulphides. It is not known how far beyond the borders of the map this rhyolite body extends.

Latite is the most abundant rock of the district. It extends in a continuous strip from the north to the south, with extensions to the eastern edge of the mapped area. In this formation are to be found some of the principal ore veins of the district, including those of Kerber Creek, Copper Gulch, and Eagle Gulch.

The andesite of the Bonanza district shows a great variation in texture and in composition. In the northwest portion of the mapped area the andesite contains abundant hornblende. Elsewhere this mineral is nearly or quite missing. The frequent occurrence of amygdaloidal texture and of interbedded tuffs show that this rock was laid down in a succession of surface flows. It is also to be found in narrow dikes intersecting the latite.

Rhyolite

MEGASCOPIC CHARACTER—

The rhyolite of this district is of a light gray to nearly white color. This is clearly shown by the fact that East and West Porphyry peaks, the upper part of which is nearly bare of vegetation and of soil, stand out very conspicuously by their excessive whiteness. The white color is usually increased by weathering. At the same time the joint planes may in places be stained to a brownish color by the deposition of limonite. There is considerable variation in structure and texture, due doubtless, in part, to the fact that the rhyolite mass is composed of several or many individual flows. Flow structure is usually not greatly in evidence and may be entirely lacking. In other places it is very markedly developed so as to cause the rock to split up into thin slabs under the influence of frost. This feature is beautifully shown on the summit of East Porphyry Peak, which is strewn with such rhyolite slabs (see Plate IX, Fig. B, opposite page 24). On the southwestern slope of this peak less than one hundred feet below the summit the rock can readily be split into thin plates a foot square and one-quarter to one-half inch in thickness. These flow planes are sometimes straight, at other times curved and twisted.

This rock is not conspicuously porphyritic, the phenocrysts being small and usually not over-abundant. These consist of orthoclase and biotite. The orthoclase is the colorless, glassy variety customarily called sanidine. They are fairly abundant, but small, measuring from one to three mm. in diameter. They are nearly always fresh. The biotite phenocrysts are black and lustrous in the fresh rock, bronze-brown in the somewhat altered varieties. They occur in sharp hexagonal plates about a mm. in diameter, and are usually very sparingly developed. Quartz is apparently entirely missing as a phenocryst.

The groundmass of these rocks is either cryptocrystalline or very fine grained, never glassy, except in case of the rhyolite pitchstones described below. It varies somewhat in color. In the freshest portions it varies from gray to light gray. In the less fresh or in the less finely crystalline rocks it becomes nearly white. The rhyolite that forms the dike to be seen on the map at B3, at the northern edge of the territory surveyed, is of a drab color, very homogeneous and apparently all or nearly all groundmass. This appearance, however, is deceptive, in that the orthoclase is far from fresh and is altered to a color exactly like that of the groundmass.

MICROSCOPIC CHARACTER—

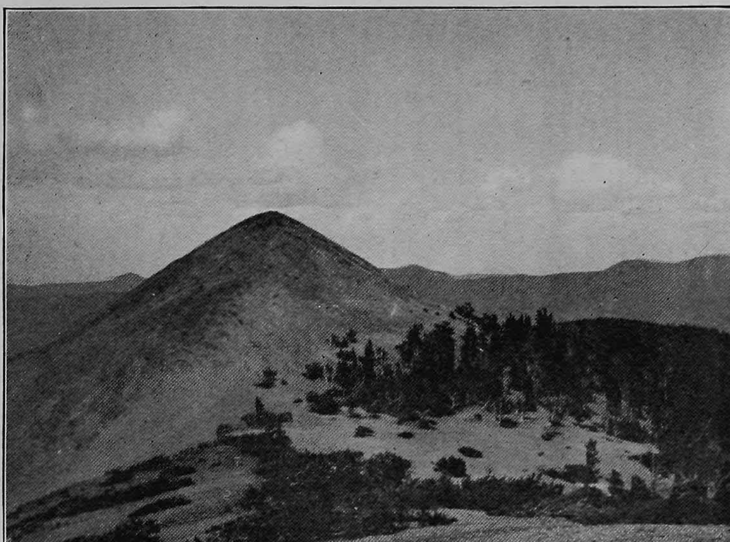
Both orthoclase and biotite phenocrysts are usually extremely fresh. The orthoclase shows no kaolinization or sericitization, except in the above mentioned rock from the dike at the northern edge of the territory. It shows the customary sharply defined crystal forms and, occasionally, Carlsbad twinning. Biotite is dark brown in color, very fresh, and never altered to chlorite. In basal sections it shows hexagonal and in vertical sections rectangular shapes.

The groundmass is usually too fine grained to admit of a definite determination of its constituents. Where the flow structure is pronounced the groundmass appears in alternately finer and coarser lines. The coarser parts can be definitely determined as orthoclase and quartz. The former shows a lower and the latter a higher index of refraction than that of the Canada balsam. Much of the feldspathic material in the groundmass shows a dusty appearance, and is evidently altered to some extent. The alteration product may be kaolin, but this could not be proven. In two instances sharp scales with parallel extinction and rather strong double refraction, and other properties suggestive of sericite, were observed.

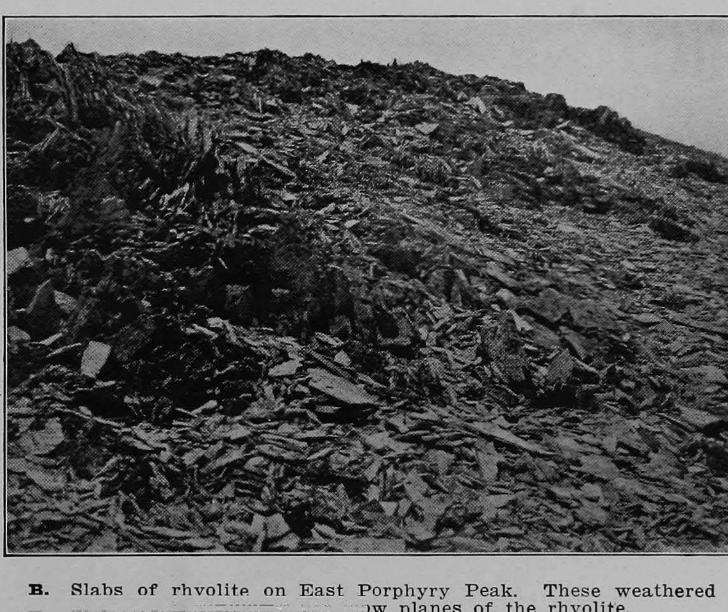
Spherulitic development of the rhyolite was observed in only one place, near the southern end of the main mass. The individual spherulites are less than a quarter of an inch in diameter. Many of these occur bunched together to form roundish balls an inch and a half in diameter, suggestive of compound spherulites.

CHEMICAL ANALYSIS—

The analysis given below and also those that follow under the head of latite and andesite were carried out in the chemical laboratories of the University of Colorado by Messrs. George Roher and Esbon Y. Titus. The analysis herewith presented under column A is that of a rhyolite (Specimen No. B 11) collected on the ridge running southwest from the summit of East Porphyry Peak. The rock has a strong flow structure and contains pheno-



A. East Porphyry Peak, as seen from West Porphyry Peak.



B. Slabs of rhyolite on East Porphyry Peak. These weathered [illegible] ow planes of the rhyolite.

crysts of sanidine, also a very few small biotite crystals, but no quartz.

ANALYSES OF RHYOLITES

	A	B		A	B
SiO_2	71.57	71.39	H_2O+	1.06[2]	3.32[4]
Al_2O_3	16.84	14.13	TiO_2	0.34	0.17
Fe_2O_3	0.63	0.63	ZrO_2	0.05	
FeO	0.07	0.37	CO_2	trace	
MgO	0.29	0.08	P_2O_5	none	0.03
CaO	0.31	1.01	MnO	trace	trace
Na_2O	3.05	2.89	Cl	trace	
K_2O	5.56	5.69	SO_3	none	
H_2O	0.28[1]	0.42[3]	S	none	
			BaO		0.09
			SrO		trace
				100.05	100.22

This analysis indicates a rhyolite comparatively low in silica and a little high in alumina. The low percentage of silica may account for the absence of quartz phenocrysts. The very small amount of biotite visible in the rock is reflected in the extremely low percentage of iron and of magnesia. Soda, while considerably lower than potash, is still high enough to suggest the presence of more soda plagioclase than an examination of the thin section of the rock would indicate. It is possible, of course, that part of the soda is combined with potash in the sanidine. The presence of a little zirconia is undoubtedly due to accessory zircon, which, however, could not be found in the thin section. The titanium found by chemical analysis cannot positively be identified with any titanium-bearing mineral. It is probably present in the dusty particles that render the groundmass more or less cloudy, quite likely in the form of leucoxene.

The analysis given under column B is that of a rhyolite very similar chemically to the Porphyry Peak rhyolite and given here for the sake of comparison. The analyses was made by Hillebrand[5] in the laoratories of the U. S. Geological Survey. The rhyolite

1, at 110°. 2, above 110°.
3, at 100°. 4, above 100°.
5. Bull., U. S. Geol. Survey, No. 419, 1910, p. 145.

occurs three and one-half miles southwest of Grizzly Peak, Plumas County, California. The rock contains "sanidine, with less quartz and biotite, in a glassy groundmass."

These two analyses are closely alike so far as the silica, iron and the alkalies are concerned, but the California rock contains less alumina and more lime.

Rhyolite Pitchstone

MEGASCOPIC CHARACTER—

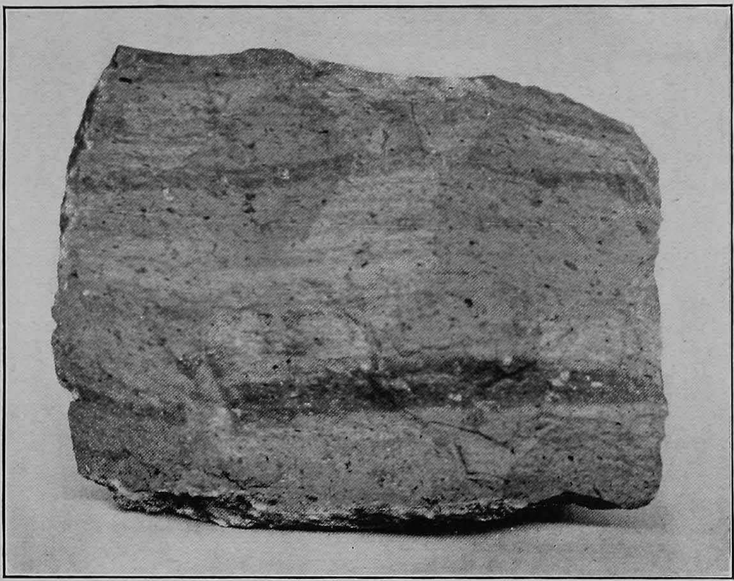
This rock was found in two places, one at the bottom of a small gulch on the southeast base of West Porphyry Peak, the other on the ridge that connects this peak with East Porphyry Peak. It varies in color from a light yellowish or grayish green to a brown or yellowish brown. The glass that forms most of the rock is fresh and lustrous with a waxy rather than pitchy luster. Small phenocrysts of glassy sanidine are abundant. Biotite is very sparingly developed, and quartz is missing.

On the above mentioned ridge the rhyolite pitchstone passes by insensible degrees into lithoidal rhyolite, also into a rock of similar character, but apparently brecciated. It does not appear, therefore, to form an independent flow, but may be considered a local, probably a surface development of a larger mass.

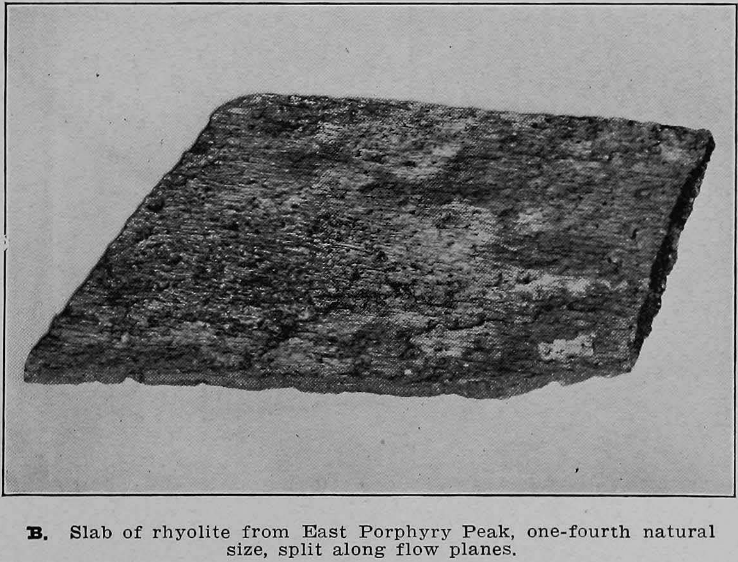
MICROSCOPIC CHARACTER—

Phenocrysts of sanidine are abundantly developed and measure up to two millimeters. They are mostly perfectly fresh and show sharply developed crystal forms, or broken fragments of such forms. Occasionally they contain enclosures or embayments of the yellow glass of the groundmass. A very few plagioclase crystals may also be seen among the phenocrysts. Biotite shows the same appearance as in the lithoidal rhyolites described above.

The glass of the groundmass is yellowish in color in the two slides examined. It shows a distinct tendency toward a perlitic separation. Numerous brown trichites in the shape of curved hairs may be seen. These show a tendency to form in clusters. Except for a small amount of devitrification material of uncertain nature, which is to be seen in a slide from the West Porphyry Peak ridge, there does not appear to be any other crystalline material in the groundmass.



A. Rhyolite, from near southern end of rhyolite mass, two-thirds natural size, showing flow structure.



B. Slab of rhyolite from East Porphyry Peak, one-fourth natural size, split along flow planes.

Rhyolite Tuff

MEGASCOPIC CHARACTER—

The rholite tuffs appear to be extensively developed on the West Porphyry Peak. Specimens were studied from three localities, first, from a point 300 feet south of the summit, second, from a point 1,500 feet south of the summit, third, from the ridge running towards the saddle between the two peaks. This last place is the same from which the above described rhyolite pitchstone was obtained. The first of these two (Specimen No. B 121) is distinctly brecciated in appearance. It shows small, whitish rock fragments a quarter of an inch in diameter or less, and a great abundance of sanidine crystals and grains, also visible quartz grains. The third specimen (Specimen No. 134) is roughly stratified, varying in color, coarseness and in amount of crystalline matter.

MICROSCOPIC CHARACTER—

These tuffs differ from the solid rhyolite in containing considerable quartz. The quartz is not confined to the groundmass, but forms an appreciable part of the crystals and fragments of crystals that make up much of these tuffs. Both sanidine and quartz appear mostly in the form of crystal fragments. These fragments together with whole crystals and bits of rhyolite groundmass or of pitchstone are cemented together with quartz or with amorphous matter of uncertain nature. Opaline silica is probably abundantly developed. No kaolinite was noted.

Latite

DEFINITION—

The name latite was first used by F. L. Ransome in 1898, and was applied to certain lava flows, notably that of Table Mountain, in California.[1] In justifying the introduction of a new rock name Ransome says it "seems advisable to attempt to bring into common use some more general name to embrace all the effusive rocks standing chemically between the typical trachytes and the typical andesites—a name that can be used as the effusive equivalent of the increasingly important plutonic group of monzonites."[2] The

1. Some lava flows of the Western Slope of the Sierra Nevadas. Bull., U. S. Geol. Sur., No. 89.
2. Loc. cit., p. 64.

justification for such a name was placed on the large and increasing number of terms in use for various types of such intermediate rocks, as, for instance, trachy-andesite, trachy-dolerite, andesitic trachyte, and Washington's more recently coined vulsinite[1] and ciminite[2].

Ransome calls attention to the fact that, even the term vulsinite, which was supposed to represent the effusive equivalent of the monzonite, does not, as defined by Washington, represent all such effusive equivalents but only certain types.

The term quartz latite has similarly been employed by Ransome to represent the effusive equivalent of the quartz monzonite. To use his own language, "quartz latite is a glassy or fine grained (micro-crystalline) rock, of which the silica content is between that of rhyolite and andesite. As a rule it is porphyritic. It contains orthoclase, plagioclase, usually oligoclase or andesine, quartz, and a small amount of one or more of the ferromagnesian minerals—dark mica, hornblende, and pyroxene. It is the volcanic equivalent of quartz monzonite and occurs as flows and dikes[3]."

DISTRIBUTION—

Latite forms the most extensively developed rock in the Bonanza district, covering, perhaps, two-thirds of the area surveyed. As will be seen from the following descriptions and from a study of the chemical analyses furnished, the rocks to which this name has been given vary very considerably in mineralogical and, therefore, in chemical composition; also in texture. Some of these rocks are free from visible quartz while others contain sufficient quartz to justify their being designated as quartz latite. Others, in the absence of quartz will be designated in accordance with the most abundant or most striking ferromagnesian mineral. The term Bonanza latite has been applied to the type of latite that is the most abundant of all, that occurs in the area immediately around the town of Bonanza, and that is characterized by unusual and interesting structural features.

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1. Jour. Geol., Vol. IV, 1896, p. 553.
2. Ibid. Vol. IV, 1896, p. 838.
3. Bull. U. S. Geol. Sur., No. 407. 1910 p. 54

BONANZA LATITE—

Megascopic Character—

Two most striking features of this rock that call for description are: first, a brecciated structure; second, a flow structure, Wherever the Bonanza latite occurs it is seen to contain small angular fragments of another rock. These fragments are seldom over two or three inches in diameter, usually less than one inch, and, more frequently still, a half inch or even much less. They may be extremely abundant and form over fifty per cent of the bulk of the rock. In this case the rock can hardly be distinguished from an ordinary volcanic breccia. More usually the fragments are sparsely scattered through the latite. They may be so sparingly developed as not easily to be seen, only one or two small fragments being visible in a hand specimen; but they are almost never missing. A further interesting fact is that these fragments in the latite are foreign to the rock. They do not consist of latite but are without exception composed of andesite, the same, apparently, as that which forms surface flows over a considerable part of the Bonanza district. For this reason if for no other it is impossible to consider these rocks as true volcanic breccias.

As will appear later, a microscopic examination of these rocks shows that the rock mass that encloses the above mentioned fragments of andesite is a true lava rock with all the characteristics that distinguish a lava from the cementing material of a volcanic ash or breccia. This occurrence of fragments of igneous rock enclosed in a massive lava flow in such abundance as to resemble volcanic breccias is by no means an uncommon occurrence in the Tertiary volcanic regions of Colorado. It was first described by Cross[1] as occurring in the Intermediate Series and the basal member of the Potosi series and was designated by him a flow-breccia. Speaking of this occurrence, Cross says: "The fragmental character is most evident near the bottom of the band, and in several sections a massive flow with many inclusions—a flow-breccia—follows without any clearly defined line of separation; in fact, some specimens collected to represent supposed gravelly tuff were found on microscopical examination to be flow-breccia."

Other flow-breccias have subsequently been described by Cross as occurring in the San Juan mountains. Some of these resemble

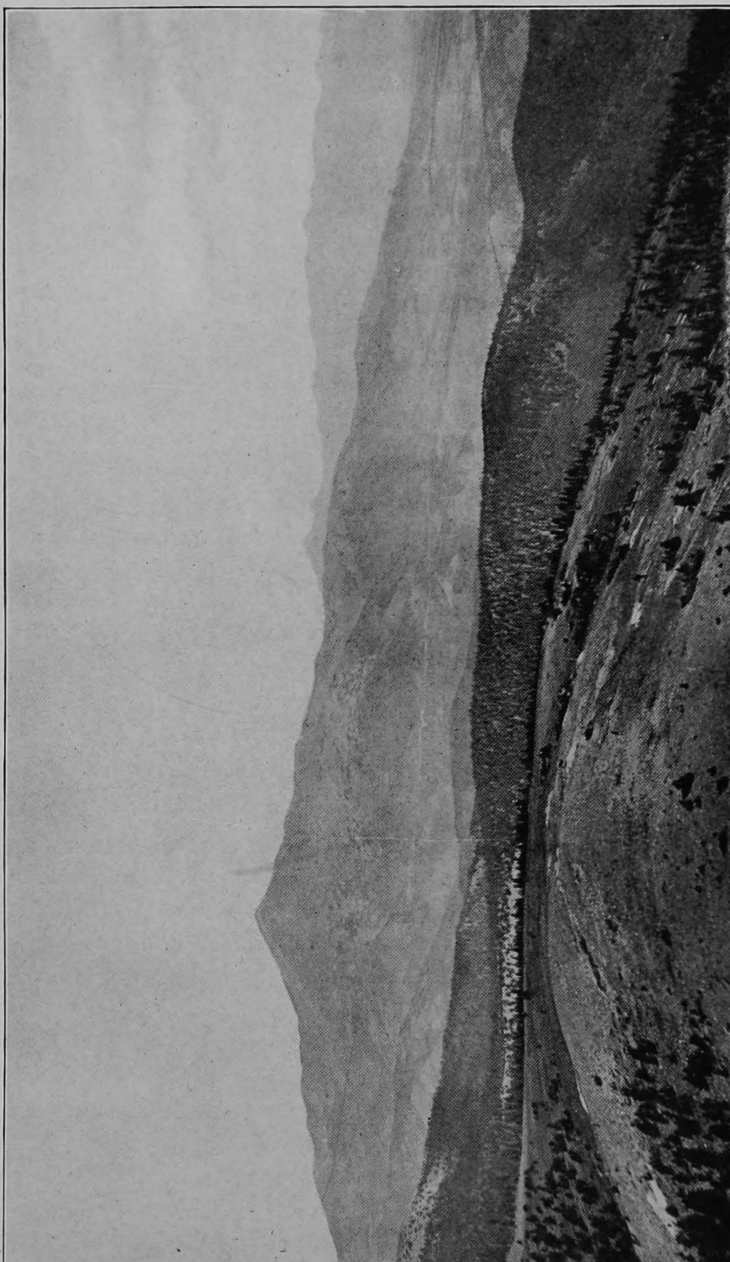
1. Cross, Whitman, Geol. Folio, U. S. Geol. Survey, No. 57, 1899.

the flow-breccias of the Telluride quadrangle in that the enclosed fragments are of different character from that of the lava flow. This is notably true of a flow-brecca in the Silverton quadrangle to which the name Eureka rhyolite has been given. Of this rock Cross says[1]: "The second member of the Silverton series is a rock belonging to the most siliceous of the magmas which were erupted during this epoch of the San Juan volcanic history. It is so characterized by small included fragments of andesites, of rocks very similar to the rhyolite itself, or occasionally of granite, schist, etc., and has so commonly a distinct flow-structure, that much of the rock may be called a flow-breccia. . . . Normally it is a grayish rock exhibiting many small angular inclusions, averaging much less than half an inch in diameter, of dark, fine-grained andesites or of reddish or grayish rhyolite, and has a prominent fluidal texture in the dense felsitic groundmass which holds the fragments."

A flow-breccia has also been described by Crawford[2] as occurring on Brittle Silver Mountain in the Monarch-Tomichi district about twenty miles northwest of Bonanza. In this case the flow-breccia contains fragments of porphyry not identical with the material composing the lava flow in which they are enclosed.

A flow-breccia, then, according to the definition established by Cross, may be considered to be a rock having an outward resemblance to a true breccia, the cementing material of which is a massive lava. The enclosed fragments may be of the same nature as that of the enclosing lava, and often are, but they may be very different in character according to their source. It is interesting to note that the Eureka rhyolite of the Silverton quadrangle is a flow-breccia in which the fragments are mostly andesite, as is the case with the Bonanza latite. According to the observation of the writer flow-breccias are so common a feature among the igneous rocks of Colorado and other Cordillaran states that they deserve more emphasis than has heretofore been placed upon them, and a term description of this manner of occurrence would be welcomed. He would suggest, therefore, that the term **rhyoclastic** might well be used as an adjective description of the texture of a flow-breccia. A **rhyoclasic rock,** then, would be an igneous rock containing numerous fragments of similar or different rock material which, when the enclosed fragments are

1. Geol. Folio, U. S. Geol. Survey, No. 120, 1905, p. 7.
2. Crawford, R. D., Bull., Colorado Geol. Survey, No. 4, 1913, p. 176.



Mount Ouray as seen from the summit of Round Mountain.

sufficiently numerous, may closely resemble a true breccia. The term rhyoclastic may well be employed to describe the occurrence of such enclosed fragments without regard to their abundance.

The term flow-breccia has also been employed in a somewhat different sense from that discussed above. In his book on Igneous Rocks, Iddings[1] writes as follows: "When exploded fragments of molten magma, large or small, fall together in a still heated condition, as may readily happen within the crater of a volcano or in the mouth of a fissure, they may be plastic enough to weld together in a more or less compact, coherent mass. This may subsequently flow like other lava, and is known as flow-breccia."

While such rock can very properly be called a flow-breccia it does not seem to the writer as wise or in accord with well established custom to change the definition as originally given by Cross. In the case described by Iddings it might avoid confusion if the term welded flow-breccia were employed.

Both types of rock are important and should be recognized in geological nomenclature. It would be possible to retain the name flow-breccia for both types and avoid all confusion by designating the earliest described type as a rhyoclastic flow-breccia, while for Iddings' type the term welded flow-breccia would apply.

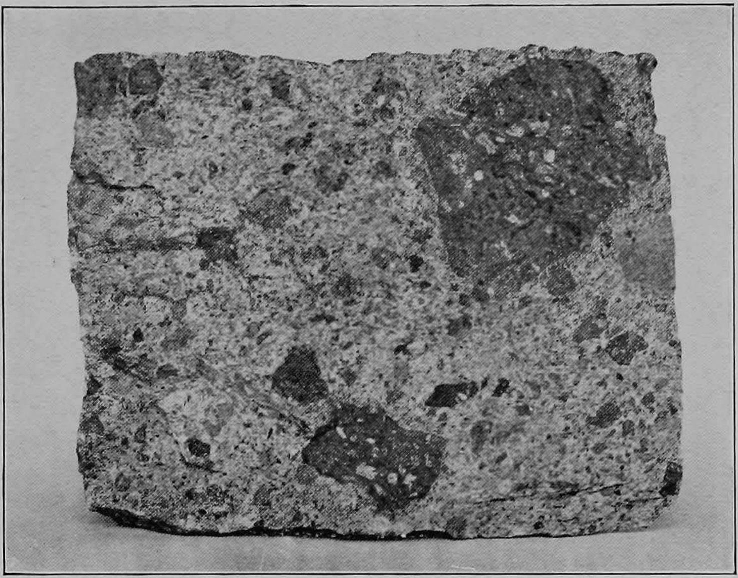
The Bonanza latite with a more or less pronounced rhyoclastic texture has been observed to extend for a considerable distance to the south beyond the boundaries of the surveyed district. They have been traced along the Kerber Creek valley to a point eight miles below Bonanza. This rock, therefore, extends a total distance from north to south of at least twelve miles, and throughout this distance it is characterized by this rhyoclastic texture. It is difficult to account for the occurrence of these small bits of andesite scattered so uniformly through the latite over so wide a stretch of country. There are three possible sources for these fragments. First, they may have been picked up by the latite as it broke through beds of andesite breccia. Against this supposition is that fact that, in this case, the fragments ought to vary more in size and not be so uniformly small. Furthermore, it seems almost impossible to believe that the fragments could under such conditions be so evenly and uniformly distributed. Second, the latite stream may have flowed over a surface heavily covered with andesite tuff and breccia. The same objections

1. Iddings, J. P., Igneous Rocks, Vol. I, 1909, p. 331.

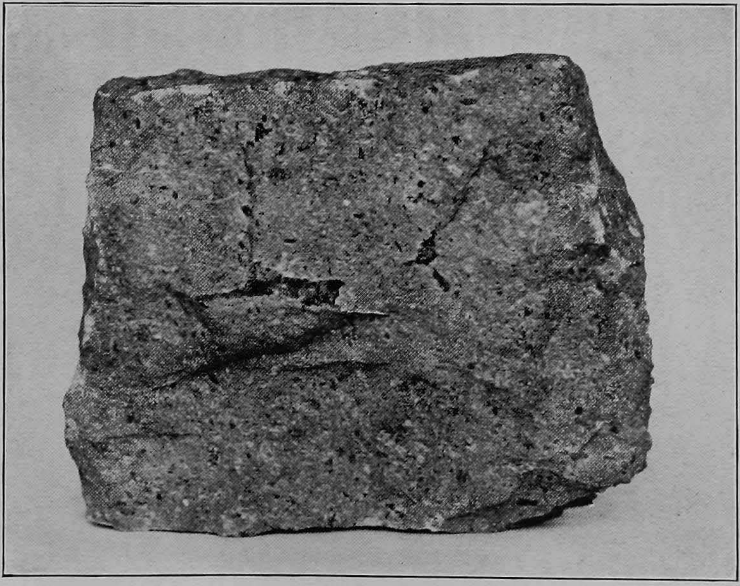
would seem to apply to this as were given for the first source. Third, a fresh surface flow of latite lava may have been thickly sprinkled by a shower of andesite fragments from some neighboring volcanic vent. There are perhaps still greater difficulties involved in this theory. This might account for a wide distribution of the fragments but it would hardly account for their being distributed throughout the latite flow vertically. Indeed, it is doubtful whether these very small fragments would sink through the latite mass to any appreciable extent, as the latite would quickly crust over and become solid on the surface. We might, perhaps, conceive of a more or less steady showering of a latite lava stream by andesite fragments at the source, kept up during the entire period of flow.

Another feature that characterizes the Bonanza latite is a very marked flow texture. This is made evident in the field by an apparent bedding of the rock that causes it to cleave readily along the flow planes. This rock cleavage and the finer flow-lines are usually very pronounced on the weathered surface, but may hardly be noticeable in the fresh rock. This apparent bedding of the lava together with the rhyoclastic texture often causes the resemblance to a bedded breccia to be almost perfect. In places the bedding produced by flowage is evident in the larger structural features and an outcrop of some extent may show a dip and strike like that of a sedimentary rock. This is well brought out in Plate III, frontispiece.

In fresh condition this rock has a dark, blackish gray color and is composed of a felsitic groundmass thickly crowded with small phenocrysts of feldspar and biotite. Both feldspar and biotite phenocrysts measure between one and two millimeters in diameter. The biotite is in the form of sharp hexagonal tablets of black or brownish black color. They are not quite so abundant as are the feldspars. The latter sometimes show albitic twinning strations. Fresh latite or even approximately fresh latite is very seldom to be found on the surface, or even in the mine workings. In some places the rock appears to be far from fresh and has a brown color. In reality, however, the brown colored latites turn out to be nearly as fresh as those with the blackish gray groundmass, the color being due to limonite stain. The oxidation has completely changed the color of the felsitic groundmass but has hardly affected the biotite or the feldspar at all. More usually the color of these rocks is a gray or drab. In places they may



A. Bonanza Latite, specimen B17, from small tunnel near portal of Rawley drainage tunnel; two-thirds natural size. Shows rhyoclastic structure, with enclosed fragments of andesite.



B. Eagle Gulch latite, specimen B51, from south side of Elkhorn Gulch; five-sixths natural size.

be leached out to nearly white. Alteration has in most cases changed the biotite crystals to green, due to the development of chlorite. In the lightest colored rocks the chlorite appears to have been completely removed.

The rhyoclastic structure is often very pronounced where alteration has made considerable progress. This is particularly well shown in a rock that came from a tunnel immediately west of the portal of the Rawley drainage tunnel in Squirrel Gulch. A photograph of a hand specimen of rock from this tunnel is shown in Plate XII, Fig. A. In the fresher portions of the Bonanza latite the rock has a distinctly andesitic habit and there is very little contrast between the latite and the included fragments of adesite. The contrast is brought out by weathering.

Microscopic Character—

Groundmass.—These rocks show a very great variation in the relative amounts of phenocrysts and of groundmass, also in the number, size and abundance of the enclosed fragments. Almost always the flow texture is very pronounced, both in the fresh and in the altered forms. This texture is well shown on Plate XIII, Fig. A. These rocks undoubtedly contained much glass in the groundmass when fresh but in most cases devitrification products have completely replaced the glass. These alteration products consist of quartz, orthoclase, sericite, chlorite, calcite and, apparently, opal. Yellow or brown staining due to hydrous iron oxide is locally pronounced but is probably due to superficial oxidation. In most cases the alteration products of the groundmass are so minute or obscurely developed as to render a positive identification impracticable.

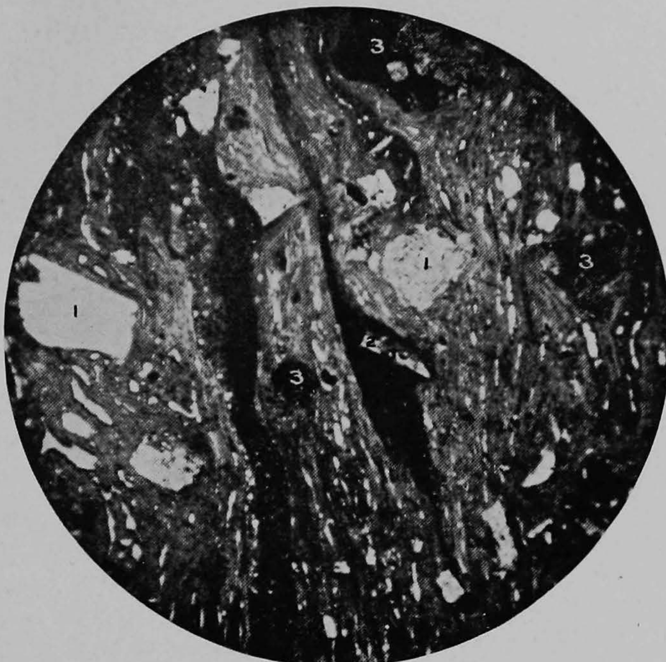
In some of the fresher specimens of this rock amorphous material, presumably glass, is preserved. It is usually clouded with blackish, dust-like specks, or contains innumerable minutest particles that show high refraction and strong double refraction. In a number of cases rod-like microlites are abundantly developed (see specimens B127, B213, B235). In one case (see specimen B127) these microlites show strong double refraction and oblique extinction, and are considered to be augite. The microlites measure approximately .001 mm. in width and .01 mm. in length (see specimen B2). In other cases, in place of these rod-like microlites, there appear rows of opaque black specks, six or eight in number, strung along a straight line of about the same length

PLATE XIII—Photomicrographs of Bonanza latite.

A. Specimen B142, from the summit 4000 feet northwest of Round Mountain. ×20. White light. Shows flow-texture and 1, orthoclase; 2, biotite; 3, incosed fragments of andesite.

B. Specimen B35, from a narrow sheet in andesite in Rawley Gulch above the Rawley mine. ×15. White light. Shows flow-texture and inclosed fragment sof andesite.

Colorado State Geological Survey. Bulletin No. 9, Plate XIII, A



Colorado State Geological Survey. Bulletin No. 9, Plate XIII, B

as the microlites and having intervening blank spaces. These very probably represent alteration products of the original straight microlites.

Phenocrysts.—Phenocrysts are mostly small but very numerous. Plagioclase, orthoclase and biotite occur in all cases and occasionally a little quartz. The most abundant of the phenocrysts is plagioclase. As determined by the maximum symmetrical extinction angles these appear to vary from andesine to labradorite. In three cases these extinction angles measures respectively 17°, 22° and 26°. In size they usually vary from 1 mm. or less up to 2 mm. or possibly 3 mm. in length. Occasionally they may occur in skeleton forms. The most common alteration product of the plagioclases is sericite in minute scattered scales. Less commonly we find epidote and calcite or a mixture of both of these with sericite.

Orthoclase is less abundantly developed than is the case with plagioclase. It is likely to occur in somewhat larger and not abundant crystals. Like plagioclase it is subject to alteration into sericite. Biotite is in most cases a very abundant phenocryst and occurs in crystals about the same size as the plagioclase. Where unaltered it has a deep brown color in thin section (see specimens B2, B273. In the great majority of cases it shows more or less complete alteration, the most common alteration product being chlorite, in addition to which there may occur epidote, calcite, and muscovite. Apatite and magnetite occur as accessory constituents.

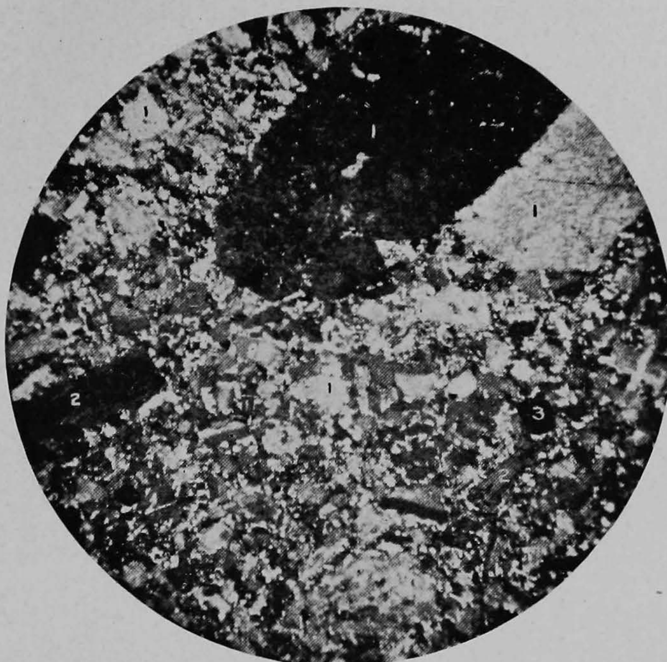
Inclosed fragments.—As already remarked the inclosed fragments found in the Bonanza latite are invariably andesite. Under the microscope it may be seen that these fragments are often very small and extremely abundant. They evidently represent andesitic rocks that vary greatly in texture but not apparently in mineralogical composition. Upon the whole they represent rocks quite similar to the andesite flows of the Bonanza district. They are all markedly porphyritic and show plagioclase in two generations. Usually alteration has progressed so far that the ferromagnesian minerals are no longer recognizable. On the other hand the plagioclase is well preserved in the groundmass as well as among the phenocrysts. The most characteristic texture is hyalopilitic, but this passes into stages where the groundmass is more or less completely crystalline. The original glass appears to be

PLATE *XIV.*

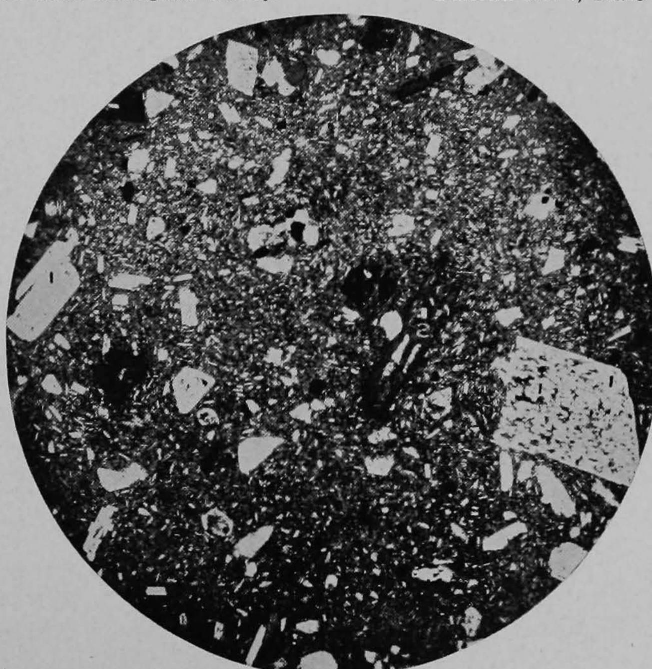
A. Photomicrograph of Eagle Gulch latite, Specimen B51, from the south side of Elkhorn Gulch (same rock as shown in Plate XV, B). ×20. × nicols. Shows 1, orthoclase; 2, plagioclase; 3, magnetite.

B. Photomicrograph of hornblende-biotite latite, Specimen B10, from Squirrel Gulch above the saw mill (same rock as shown in Plate XV, A). ×15. White light. Shows 1, plagioclase; 2, hornblende, the latter corroded.

Colorado State Geological Survey. Bulletin No. 9, Plate XIV, **A**



Colorado State Geological Survey. Bulletin No. 9, Plate XIV, **B**



entirely replaced by alteration products that sometimes are recognizable as epidote, calcite, chlorite, etc.

EAGLE GULCH LATITE—

Distribution and Megascopic Character—

This rock is properly a quartz latite in that it contains an appreciable though not very great percentage of quartz. It forms the country rock on both sides of Eagle Gulch from a short distance above the Villa Grove road up to nearly the head of the gulch. From Eagle Gulch this latite extends in a northeasterly direction and crosses the Hayden's Peak range about two miles north of the peak. Whether this type of rock extends any great distance beyond the southern limit of the map on the south of Eagle Gulch was not determined. The northern boundary of the Eagle Gulch latite crosses over the divide between Eagle and Elkhorn gulches, follows for some distance the course of Elkhorn creek, and continues along the bottom of the right hand or southern fork of this gulch up to the summit of the range.

The most striking distinction between this type of latite and the Bonanza latite lies in the complete absence of both flow and rhyoclastic structures. The fragments of andesite that are everywhere to be seen enclosed in the Bonanza latite are completely absent from this rock. In not one instance was such a fragment observed. Similarly the cleavage due to flow structure is also conspicuously absent. The rock represents a fairly uniform appearance over most of the territory. The color is light gray. In only one case (Spec. B73) did the rock become dark gray. The groundmass is holocrystalline and of medium grain, but not coarse enough to disclose the constituents of which it is composed. Feldspar phenocrysts are abundant but inconspicuous as they have almost exactly the same color as that of the groundmass. They never reach dimensions of more than quarter of an inch and usually not more than one-eighth of an inch in diameter. Orthoclase can usually be identified, and sometimes plagioclase. Biotite, never fresh, occurs in greenish or grayish green hexagonal plates up to 2 or 3 mm. in diameter. Quartz is never visible.

Microscopic Character—

Groundmass.—The holocrystalline character of the groundmass is very plainly evident under the microscope in that the crystals and grains are usually large enough to permit of a ready identification of the component minerals. With few exceptions quartz is present in appreciable quantity but does not in any case make more than perhaps one-tenth of the bulk of the rock. The quantity of quartz fluctuates sufficiently to make it inadvisable to classify this rock strictly as a quartz latite, but in the normal occurrence of this rock this name can properly be applied.

The feldspar of the groundmass is almost entirely orthoclase. A little plagioclase may be identified, always in distinctly rectangular crystals that are surrounded by a margin of orthoclase. Such plagioclase crystals may, perhaps, be looked upon as smaller plagioclase phenocrysts rather than strictly groundmass constituents. In the normal development of this rock (Spec. B51, B66), the orthoclase occurs in rectangular crystals or in roughly rectangular grains. Quartz occurs as a sort of cement between the orthoclase crystals, always in small irregular grains, or, less frequently, in irregular patches that show simultaneous extinction and that more or less completely surround an orthoclase grain or crystal. The feldspars have a clouded appearance owing to the development of kaolin and have a grayish brown color. Accessory magnetite and apatite are sparingly developed. Secondary carbonates are also sparingly represented.

This rock may be found normally developed (Spec. B51) along the south side of Elkhorn Gulch where the line of contact between the Bonanza latite and the Eagle Gulch latite reaches the creek. In other parts of the field this rock does not always have so coarse grained a groundmass.

Phenocrysts.—The phenocrysts of this rock consist of orthoclase, plagioclase, and biotite. The relative amounts of the two feldspars varies more or less but orthoclase is more abundant and occurs in larger crystals than does the plagioclase. Like the groundmass feldspars those of the phenocrysts are clouded through alteration to kaolin. In some cases a small amount of sericite has also been developed. A symmetrical extinction angle of 23° was noted in one plagioclase crystal (Spec. B66), indicating the presence of labradorite. Biotite of the usual brown color is rather sparingly developed. It usually is altered to chlorite.

The chemical analysis of this latite is given on page 44.

Hayden's Peak Latite—

Distribution and Megascopic Character—

So far as the Bonanza map is concerned the rock that is here called the Hayden's Peak latite occupies only the summit of that peak, including that of the somewhat lower North Hayden's Peak. It doubtless extends well down the southern and eastern slopes of the peak and may possibly have a more extensive development in the region south of Hayden's Peak, but outside the mapped area. It is separated from the above described Eagle Gulch latite by a narrow strip of Bonanza latite. The rock is extremely homogeneous in appearance, has a characteristic grayish brown color as it appears exposed on the surface, and consists of numerous but hardly visible phenocrysts of feldspar, with occasional biotite, measuringly only one-half to at most one mm. in diameter, and a very abundant crypto-crystalline, felsitic groundmass. The entire mapped area of Hayden's Peak is entirely bare of soil or of vegetation and is covered with mostly small angular fragments of this latite.

Microscopic Character—

Three specimens of this rock collected on different parts of the exposed mass do not differ materially from each other. The one taken from the very summit of the peak (Spec. B70) is somewhat coarser grained than the others and offers a better opportunity for the identification of its component minerals. The phenocrysts consist of orthoclase and plagioclase in rectangular forms. Both are largely altered to kaolin and to sericite so as to make it difficult to determine their relative abundance or the exact nature of the plagioclase. The plagioclase crystals are in many cases surrounded by rims of orthoclase. Minute crystals of brown biotite are very sparingly developed.

Quartz is apparently quite abundantly developed, more so, it would seem than is the case with the Eagle Gulch latite. It occurs mostly in the form of skeleton-like or poikilitic patches, each patch showing simultaneous extinction. These poikilitic patches make up almost the entire mass of the rock, with the exception, of course, of the not overly abundant phenocrysts. They are thickly crowded with minute, roughly rectangular feldspar grains. The latter are largely kaolinized. They show no indication of albitic twinning and are taken to be orthoclase. The quartz also forms in places micropegmatitic intergrowths with the orthoclase rims around the plagioclase phenocrysts.

To some extent the material forming the poikilitic patches was determined to be orthoclase. This determination was based largely on the fact that the index of refraction is lower than that of the surrounding Canada balsam. In this case the rectangular inclosed feldspar grains may be presumed to be plagioclase.

Accessory magnetite grains are sparingly developed.

HORNBLENDE-BIOLITE LATITE—

Distribution and Megascopic Character—

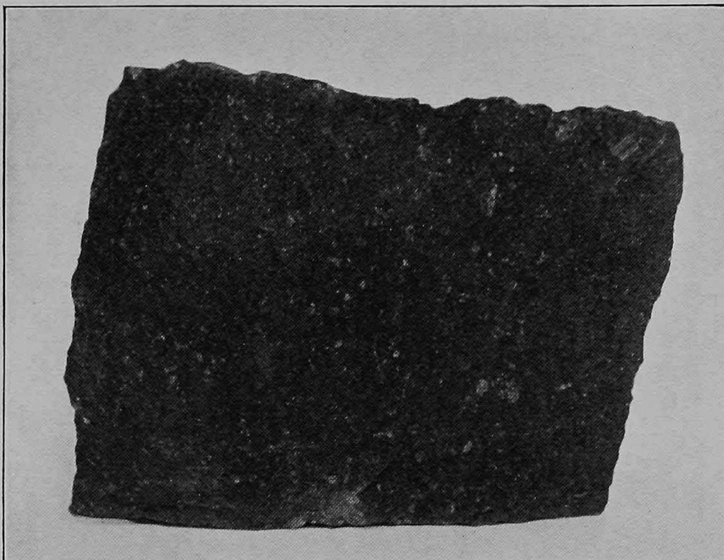
In contrast with the above described latites, in which orthoclase forms a conspicuous constituent, is a rock of markedly different appearance which is apparently free or nearly free from visible orthoclase but which, nevertheless, on account of the similarity of chemical composition, must be classed among the latites. Owing to the presence of abundant and characteristic hornblende in addition to biotite this rock is designated a bornblende-biotite latite.

Except for one dike to be found on the crest of the range, at a point about 3,000 feet northwest of the summit of Round Mountain, this rock forms a continuous sheet that apparently underlies the rhyolite, the ridge running south from West Porphyry Peak. This sheet forms the surface rock on the east and west sides, and skirts around the southern edge of this ridge.

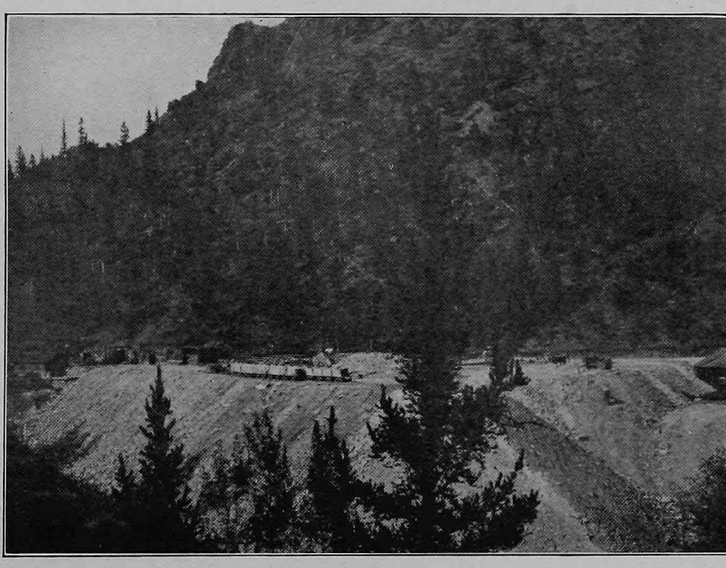
When fresh this rock is extremely black in color and appears like a basic andesite or basalt, and even where not fresh it never becomes as light colored as is the case with the Bonanza latite. The groundmass is cryptocrystalline and abundant and is not lustrous. The phenocrysts are both abundant and conspicuous. They consist of plagioclase, hornblende, and biotite. Of these biotite is usually small and inconspicuous. It seldom runs beyond 2 mm. in diameter. It is black and often very fresh. Both plagioclase and hornblende phenocrysts are in places very much in evidence and may attain dimensions of 10 mm. The hornblende occurs in rather long prismatic, jet black crystals. The prismatic cleavage is always easily recognized. This mineral usually appears to be perfectly fresh. (See Plate 14, Fig. A.)

Microscopic Character—

Groundmass.—This rock is typically represented by a specimen (Spec. B10) collected on the prominent cliff on the east side of Squirrel Gulch, about 800 feet north of the saw mill and opposite



A. Hornblende-biotite latite. Specimen B10, from Squirrel Gulch, 800 feet above saw mill (same rock as shown on Plate XIV, B). Two-thirds natural size.



B. Portal of the Rawley mine drainage tunnel.

the place where the road crossed the creek. A chemical analysis of this rock will be found on page 44. The groundmass is hyalopilitic in texture. That is, it consists of an abundant glass of yellowish brown color in which are strewn numerous slender plagioclase laths and smaller microlites of the same mineral. No augite appears to be present. The groundmass is not, however, quite so fresh as the appearance of the hand specimen would suggest. Minute irregularly granular particles of very strong double refraction and often of high refractive powers are fairly abundant. Undoubtedly some of this may be attributed to carbonates, as the chemical analysis shows the presence of an appreciable amount of CO_2. The higher refractive material is probably leucoxene.

Specimens collected in other portions of this latite sheet as well as from the above mentioned dike differ somewhat in detail and in the degree of alteration, but are not essentially different from the specimen just described.

Phenocrysts.—The phenocrysts present are plagioclase, hornblende, and biotite. Orthoclase could not be positively identified. As compared with other latites and the andesites of the Bonanza district the plagioclase phenocrysts are better preserved. In the specimen referred to under the description of the groundmass they appear to be almost entirely free from alteration products. Some of the crystals, more especially the larger ones, are spongiform in texture, the interior being crowded with irregular groundmass inclusions (See Plate 14, Fig. B). Many of the plagioclases are fragments of crystals that have been broken in connection with the movements of the magma. The mineral is a fairly normal labradorite, as symmetrical extinction angles up to 28° were noted.

The hornblende phenocrysts have the customary brown color and strong pleochroism of similar rocks elsewhere. The pleochroic colors are: a, yellow; b, and c, brown to greenish brown and nearly alike. Narrow resorption rims, black and opaque with magnetite, are invariably present. In some cases in connection with the magmatic resorption the crystals have been irregularly corroded so that a chance section may show the interior more or less hollow and filled with groundmass material. Such a crystal is shown in Plate 14, Fig. B. Alteration forms of this rock show the hornblende altered to a mixture of chlorite and carbonates (Spec. B103).

The biotite crystals resemble the hornblende in color, but are somewhat browner and lack the slightly gleenish cast. They also show resorption rims. Accessory magnetite and apatite are present, the former being quite abundant.

DIKE LATITE—

In the large augite andesite area on the eastern side of the Bonanza district are three dikes about one-half and three-quarters of a mile apart in a general north and south line. The most northerly of these dikes appears to occur at the contact of the augite andesite and Bonanza latite; the two others cut the andesite. These dikes are situated respectively in the map locations D4, F4, and G5. In the absence of a chemical analysis they cannot be positively identified and they do not closely resemble any other rocks in the district. Only one specimen was collected from each of these dikes. Specimen B329 is from the northern dike; B327 from the middle dike, and B321 from the southern dike. All three show well rounded quartz phenocrysts three to four millimeters in diameter, B327 very sparingly, the others quite abundantly. No. B329 also shows orthoclase phenocrysts up to 15 millimeters in diameter; the others are nearly free from visible orthoclase. No. B327 has a very marked flow structure, and is grayish black. The others do not show such structure in the hand specimen, although fluidal arrangement of the feldspar microlites is somewhat in evidence in the thin section.

Under the microscope may be seen rather sparingly developed phenocrysts of orthoclase, plagioclase, and biotite. The groundmass is far from fresh, so that the original constituents are difficult to make out. Some quartz appears in irregular grains. Whether the feldspar of the groundmass is orthoclase or plagioclase cannot be determined. Secondary minerals are chlorite, sericite and epidote. The groundmass contains minute black, opaque, dust-like particles, also delicate rod-like, opaque microlites. These last are particularly marked in No. B327.

The flow structure of these dike latites would seem to suggest their affiliation with the Bonanza latite rather than with the quartz latites, as represented by either the Eagle Gulch latite or by the Hayden's Peak latite. The presence of visible quartz phenocrysts would seem to justify their being designated as quartz latites, but it is to be noted that the amount of visible quartz is small, so that these rocks may not really be more acid than the Bonanza latite. The absence of inclosed andesite fragments is also a feature that distinguishes these dike rocks. This, however, cannot be considered as conclusive against placing these dike rocks with the Bonanza latite; it can readily be understood that the maga rising through fissures might be free from inclusions of the andesite fragments that characterize the surface flows of the same magma.

CHEMICAL ANALYSES—

Three chemical analyses made in the laboratory of the Colorado State University show respectively the composition of the three main latite types of the Bonanza district, namely, the Bonanza latite, the Hornblende-Biotite latite, and the Eagle Gulch quartz latite. These are given under columns marked A, B, and C. For purposes of comparison there will be found under columns numbered 1 to 6 the analyses of latites from other districts. Columns 1, 2, and 3 represent rocks from Tuolumne Table Mountain, California, and adjacent territory to which Ransome[1] first applied the name latite. Under columns 4 to 6 are given the analyses of some quartz latites from other Colorado districts[2], and should be compared with that of the Eagle Gulch latite.

1. F. L. Ransome, Some lava flows of the Western Slope of the Sierra Nevadas. Bull., U. S. Geol. Sur., No. 89, 1898.

2. For descriptions of the rocks here referred to see as follows: column 4, Whitman Cross and Ernest Howe, Geol. Folio, U. S. Geol. Sur., Ouray Quadrangle, No. 153, 1907; column 5, Whitman Cross and Ernest Howe, Geol. Folio, U. S. Geol. Sur., Silverton Quadrangle, No. 120, 1905; column 6, R. D. Crawford, Geology and Ore Deposits of the Monarch and Tomichi Districts, Colorado Bull., Colo. State Geol. Sur., No. 4, 1913.

	A	B	C	1	2	3	4	5	6
SiO_2 ...	58.04	58.10	67.16	56.19	56.78	59.43	68.81	64.93	64.56
Al_2O_3 ..	17.89	18.72	16.03	16.76	16.86	16.68	15.54	16.79	17.36
Fe_2O_3 ..	2.17	2.01	1.67	3.05	3.56	2.54	1.78	3.54	.76
FeO ...	2.41	2.64	1.38	4.18	2.93	3.48	.80	.32	1.81
MgO ..	1.55	1.12	.77	3.79	3.41	1.84	.52	.65	.73
CaO ...	4.54	5.37	1.62	6.53	6.57	4.09	2.43	2.11	3.25
Na_2O ..	3.37	3.09	4.23	2.53	3.19	3.72	4.24	3.33	3.56
K_2O ...	4.17	3.88	5.78	4.46	3.48	5.04	4.07	4.76	5.94
*H_2O— .	.09	.92	.11	.34	.15	.27	.50	1.12	.41
‡H_2O+ .	1.70	1.99	.64	.66	1.21	.72	.78	1.65	.45
TiO_2 ...	.49	.90	.56	.69	1.15	1.38	.28	.53	.61
ZrO_2 ...	.12	trace	none	.....	.....	.....	trace	.03	trace
CO_2 ...	3.35	.81	.06	.....	.....	.....	.48	.....	.....
P_2O_5 ...	.43	.06	.05	.55	.42	.58	.13	.17	.08
SO_3	none	.37	.03	.....	.....	.....	.....	.....	.....
Cl	.02	.01	none	.....	.....	.....	.....	.....	.01
S	none	none	none	.....	.....	.....	.....	.....	.....
MnO ...	.12	.10	.12	.10	none	trace	.12	.....	.33
BaO	.....	.....	.....	.19	trace	.14	.13	.15	.....
SrO	.....	.....	.....	.....	.....	.....	.04	trace	.....
LiO_2	.....	.....	.....	.....	.....	.....	.....	.....	.....
	100.46	99.99	100.21	100.02	99.89	100.04	100.56	100.08	99.86

*H_2O— = at 110°. ‡H_2O+ = above 110°.

A. Bonanza latite, specimen B273, east of Squirrel Gulch in the northern part of the Bonanza District, map location C2. Analysts. George Rohwer and Esbon Y. Titus. Phenocrysts of orthoclase, plagioclase, and biotite. Groundmass constituents not recognizable, except magnetite, Secondary sericite and calcite.

B. Hornblende-biotite latite, specimen B10, Squirrel Gulch, north of saw mill, map location D2. Phenocrysts of labradorite, hornblende, and biotite; hyalopilitic groundmass with plagioclase microlites and magnetite.

C. Eagle Gulch quartz latite, specimen B51, Elkhorn Gulch about a mile above Kerber Creek, map location J3. Phenocrysts of plagioclase and orthoclase, groundmass holocrystalline composed of orthoclase and quartz.

1. Augite latite, Table Mountain flow, Tuolumne Table Mountain, California. Analyst, Hillebrand. Hyalopilitic texture. Phenocrysts of labradorite and augite with a little olivine. Groundmass composed of plagioclase microlites, magnetite, augite, olivine, and glass. No visible orthoclase.

2. Augite latite, Table Mountain flow, about one and one half miles east of Clover, Meadow, California. Analyst, Steiger. Contains labradorite, augite, olivine, magnetite, and a hyalopilitic groundmass.

3. Augite latite, Dardanelle flow, four miles southwest of Clover Meadow, California. Analyst, Stokes. Contains phenocrysts of labradorite, augite, olivine, apatite, and magnetite in a hyalopilitic groundmass.

4. Quartz-biotite latite (Difficulty Creek latite), Ouray quadrangle, Colorado. A finegrained porphyritic rock with small phenocrysts of oligoclase and andesine, also some biotite and large magnetic grains. Groundmass contains orthoclase and quartz. Secondary calcite.

5. Felsophyric quartz latite, Greenhalgh Mountain, Silverton Quadrangle, Colorado. Analyst, W. F. Hillebrand. Phenocrysts of sanidine and biotite and more or less decomposed plagioclase. Quartz confined to groundmass.

6. Quartz latite porphry, Mohammed tunnel, Monarch district, Colorado. Analyst, R. M. Butters. Contains phenocrysts of plagioclase, orthoclase, biotite, and hornblende. Quartz is usually confined to the groundmass.

In selecting material for a chemical analysis it was impossible to find a sample that was fresh. Also it was not easy to select portions that were assuredly free from the omnipresent inclusions of andesite. The sample that was analyzed was as fresh as was collected and was apparently free from inclusions. It is not likely that the very small amount of andesitic material that may have been present in the sample used has materially affected the result, for the reason that the andesites of this district are chemically as well as mineralogically closely related to the latites, as may be seen by comparing the analysis of augite andesite on page 54. The presence of over 3% CO_2 indicates considerable calcite in the rock, more, in fact, than an examination of the slide would lead one to expect. The calcium combined with the carbon dioxide may reasonably be supposed to have been an original ingredient of the latite magma united with other bases in the plagioclase and, probably, also in augite.

The predominance of K_2O over Na_2O is, of course, the most noteworthy feature, as is the case with the typical latites whose analyses are given in columns 1, 2, and 3. Ransome describes both augite and olivine as occurring in the California latites. As stated elsewhere it is more than likely that augite originally formed a considerable portion of the groundmass but it was not to be found among the phenocrysts, nor is there any evidence of olivine. The higher percentages of both iron and magnesium in the California rocks would account for the presence of these additional bisilicates.

It is of interest to note that there is a striking similarity between the chemical analyses of the Bonanza latite and the Hornblende-biotite latite, in spite of the very marked difference in their physical appearance and in their mineralogical composition. It is evident that the chemical ingredients that go to form the visible orthoclase in the Bonanza latite are to be found in the glass base of the groundmass of the Hornblende-biotite latite.

The quartz latite as seen in the analysis of the Eagle Gulch latite, found in column C, shows that nine per cent higher silica and also appreciably higher percentages of the alkalies than is the case with the Bonanza latite. A corresponding decrease in CaO, MgO, FeO, and Fe_2O_3 is also manifest. The analysis of the quartz-biotite latite from the Ouray Quadrangle, Colorado, given under column 5, shows a remarkably close resemblance to that of the Eagle Gulch latite.

Andesite

CLASSIFICATION AND DISTRIBUTION—

Owing to the extensive alteration to which the andesites of this district have been subjected a satisfactory classification is not possible. The ferromagnesian minerals upon which a classification of the andesites would naturally depend seem to have been especially subject to decomposition, so that, in the great majority of cases, it is not possible to determine with certainty just which one of these dark colored minerals was originally present. It would seem, however, that a two-fold division can be made based upon the presence or abundance of augite or of biotite. In the case of the fresher samples the presence of one or both of these minerals could readily be demonstrated. In others it was necessary to judge from the character and distribution of the decomposition products.

In some cases the distinction between augite andesite and biotite andesite can be made in the field, but usually this is not easy. It was not found practicable to make a distinction between these two in mapping the area under investigation. Apparently the augite andesite is the normal type, or, at least, the more abundant type. The presence of amygdaloidal structures in the andesite area is by no means uncommon. While there is reason to believe that the amygdaloidal rocks of the district belong to the augite andesites, this could not be proved because of excessive decomposition. They will, therefore, be discussed separately.

Also in case of the andesite breccias, the extreme alteration has so obliterated all traces of the original ferromagnesian minerals as to make a classification impracticable. In the field it is often extremely difficult to distinguish between andesite breccias and solid andesite flows. It is possible that the breccias are not composed altogether of andesitic material as, in places, part of the component fragments disclose a texture suggestive of basalt, or of latite. In the absence, however, of solid basaltic rocks in the district and in consideration of the difficulty of drawing a sharp line of distinction between the latite and andesite because of the altered condition of the rocks, there is no sufficient ground for considering these breccias as other than andesitic. Apparently the andesite of these breccias is augite andesite.

Next to the Bonanza latite the andesites are the most extensively developed rocks of the Bonanza district. They occur both in solid sheets and in narrow dikes. The latter are to be seen cutting the Bonanza latite in the central portion of the mapped area. The solid flows are located mostly in the eastern part of the district and form the rocks of much of the highest part of the range. Andesite forms the country rock of some of the most important ore deposits, notably that of the Rawley mine and of other mines in the Rawley Gulch district.

AUGITE ANDESITE—

Megascopic Character—

The augite andesite varies in color according to the degree of alteration from black to fairly light gray or greenish gray, the fresher rocks having the darker color. In texture they vary very largely in accordance with the size and abundance of the phenocrysts. The groundmass is never coarse grained. It may be described as fine grained to aphanitic, but not apparently glassy. Normally this rock is distinctly porphyritic in texture. As is to be expected the plagioclases form the most abundant and the most conspicuous phenocrysts. In fact, plagioclase is the only mineral that can be recognized in the hand specimen. In the common mode of occurrence the feldspathic mineral occurs in small and not very conspicuous crystals that measure not over two mm. in greatest diameter. Occasionally the size increases to five or six mm. and the rock becomes strikingly porphyritic. Every possible variation between these two extremes may be observed. The darkest colored varieties are usually less altered. In fact they appear to be extremely fresh but a microscopal examination shows that this apparent freshness is deceptive. This fine-grained, black, fresh-appearing rock is said to be extremely difficult to drill and to mine. It does not ordinarily carry ore, but it is not infrequently pierced in tunnels and cross-cuts.

Microscopic Character—

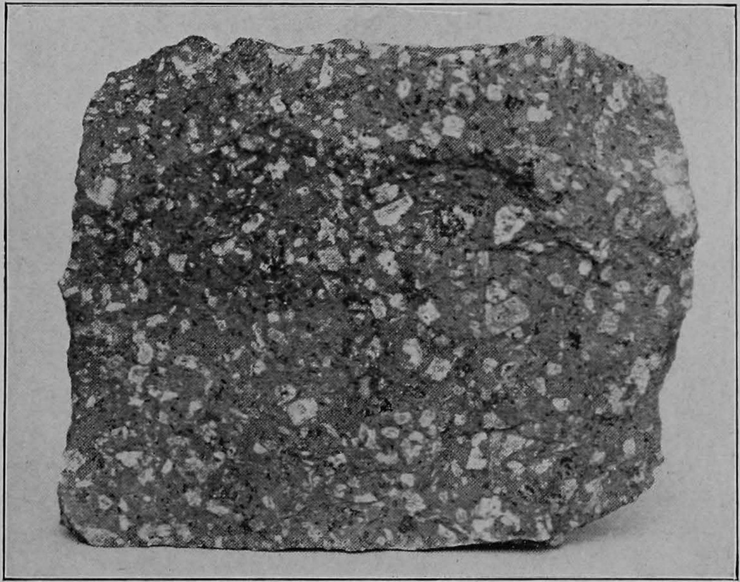
Groundmass.—To judge from the very few relatively fresh specimens collected (Spec. B3, B59, B65), the groundmass of these rocks may be described as holocrystalline to hyalopilitic. In the holocrystalline type the groundmass is composed of plagioclase, augite and magnetite. The plagioclase occurs mostly in short-rectangular crystals. The augite in every case examined is represented only by its alteration products, chlorite and carbonates. In the hyalopilitic type slender strips of plagioclase, some of which show twinning stripes and some not, occur abundantly in a glass base. The glass base appears to have been completely devitrified. Between these two types there are intermediate

Plate XVI.

A. Augite andesite, Specimen B37, from road to Sosthenes mine, two-thirds natural size. Minutely poryhritic type.

B. Augite andesite, Specimen B228, from dump of the Grand View tunnel at head of Bear Gulch. Natural size. Coarsely porphyritic type.

A



B

phases. The only case in which augite could be found undecomposed in the groundmass (Spec. B65) showed this mineral in minute prisms and in more or less irregular grains. The prisms measure about .014 mm. in length. The holocrystalline type is shown in Plate 17, Fig. B, and the hyalopilitic type in Plate 17, Fig. A. A somewhat divergent type of the holocrystalline groundmass was collected on the road leading to the Sosthenes mine (Spec. B37). In this case the groundmass appears to contain two generations of feldspar, an older generation consisting of roughly rectangular plagioclase, and between and around these a younger generation composed of irregular grains that show no twinning stripe and that are apparently orthoclase. It is possible that there is very little quartz with this orthoclase, but this could not be demonstrated. The character of this groundmass suggests the occurrence of rocks intermediate between the andesites and the latites. Only the advanced state of decomposition over most of the district makes it impossible to state how extensive such transitional types are represented.

The decomposition products of the groundmass constituents are mainly chlorite and calcite which are everywhere in evidence, even in the freshest examples. To some extent sericite is to be observed, but this mineral is not as abundantly developed in the groundmass feldspars as in the phenocrysts of that mineral.

Phenocrysts.—The only recognizable phenocrysts are plagioclase and augite. The former is everywhere present and may make up one-third or more of the bulk of the rock in exceptional cases. The latter doubtless was an original constituent of all the augite andesites, but in most cases has been completely decomposed. Out of over twenty slides examined in only three cases could undecomposed augite be found (Spec. B3, B59, B65). In some cases the augite phenocrysts alter to almost pure chlorite, in other cases to carbonates. More usually mixtures of these minerals result. Augite does not appear to have been an abundant phenocryst.

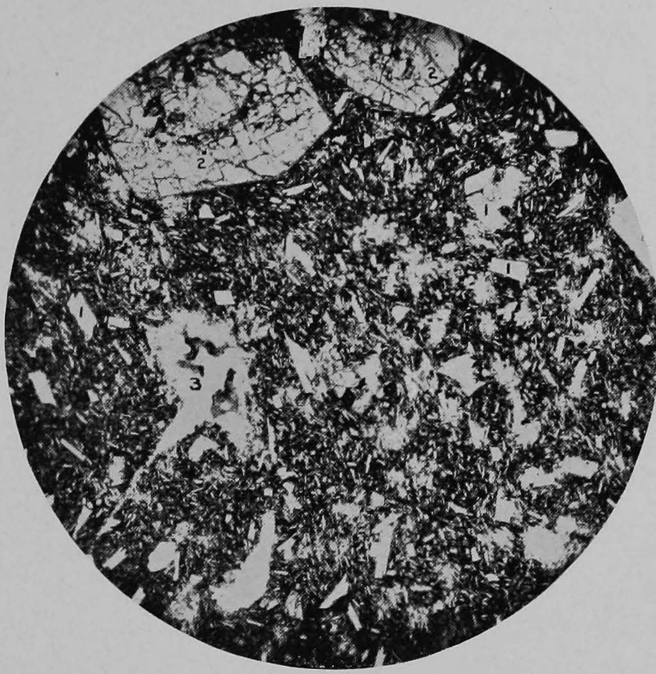
The plagioclase of these rocks is typical of the andesite family. It occurs in rectangular as well as in more complex outlines, and in all sizes up to five or six mm. Symmetrical extinction angles cut approximately at right angles to the twinning plane show extinction angles that range between 26° and 33°, and indicate a feldspar corresponding to labradorite or to labradorite-bytownite. Inclusions of the groundmass material are not uncommon. The alteration products of the plagioclase phenocrysts

PLATE XVII.

A. Photomicrograph of augite andesite, Specimen B59, from west of Kerber Creek near mouth of Elkhorn Gulch. ×15. White light. Shows 1, plagioclase; 2, augite; 3, calcite, in groundmass of hyalopilitic texture.

B. Photomicrograph of augite andesite, Specimen B3, from 2000 feet northwest of the south end of base line. ×20. × nicols. Shows distinctly only 1, plagioclase, in a holocrystalline groundmass.

Colorado State Geological Survey. Bulletin No. 9, Plate XVII, **A**



Colorado State Geological Survey. Bulletin No. 9, Plate XVII, **B**

are sericite and carbonates, also to some extent chlorite and epidote.

Amygdaloidal Development—

The augite andesite appears to be the only rock in the Bonanza district that is subject to amygdaloidal development. Such development has been noted along the road in Rawley Gulch above the Rawley mine; in Copper Gulch about a mile above the Empress Josephine mine; along the Villa Grove road opposite the mouth of Elkhorn Gulch; and in Squirrel Gulch a few hundred feet south of the portal of the Rawley drainage tunnel. In the last named case the amygdaloidal andesite does not appear on the map. The rock of the surrounding area is essentially Bonanza latite with an occasional dike or narrow sheet of andesite or a bed of andesite breccia. These andesitic rocks at this point are so poorly defined and so difficult to trace that no attempt was made to map them.

The amygdules are sometimes spherical, sometimes elongated or almond shaped, but may be quite irregular, and may attain dimensions of one-half to three-quarters of an inch. Externally they usually have a greenish color. When examined under the microscope they usually disclose a radiated structure and are seen to be composed of chlorite, carbonates, and a little quartz.

BIOTITE ANDESITE—

Megascopic Character—

The biotite andesites vary from greenish to gray and brown in color. Like the augite andesites they vary greatly in texture, some being distinctly or pronouncedly porphyritic, while others are much less so. They usually differ from the augite andesites in that the ferromagnesian mineral—in this case biotite—can usually be seen and identified in the hand specimen. It varies from brown to black in color and seldom attains dimensions over two mm. in diameter. Owing to its lack of flow structure and its complete freedom from andesite inclusions this rock need not ordinarily be mistaken for the Bonanza latite but it might readily be confounded with the hornblende-biotite latite.

Microscopic Character—

Groundmass.—The biotite is, upon the whole, still more subject to decomposition than is the augite andesite. At least this seems to be true of the groundmass materials and, perhaps, also of the plagioclase phenocrysts. On account of the extensive alteration it is difficult to determine the exact nature of the original constituents. Apparently the groundmass does not materially differ from that of the augite andesite as above described. It shows about the same variation in texture from holocrystalline to hyalopilitic. To a greater or less extent the original plagioclase strips can still be recognized. Magnetite and accessory apatite, occasionally also zircon, remain undecomposed. But the bisilicate ingredient is probably completely destroyed. There are, to some extent, granulated microlites that give the impression of having been originally augite, as is highly probable, but this cannot be demonstrated. The groundmass at present consists of remnants of plagioclase laths, magnetite, hematite scales, chlorite, carbonates, and occasionally sericite and epidote. These minerals occur in greatly varying proportions and form coarser and finer felted masses.

Phenocrysts.—The phenocrysts consist of plagioclase—in no respects different from that described above as occurring in the augite andesites—and of biotite. It is quite likely that some of the rocks originally contained augite phenocrysts. In fact certain clusters of chlorite and carbonate grains suggest the alteration products of augite crystals. The biotite appears better able to resist decomposition than is the case with augite. Quite frequently the biotite crystals are fairly well preserved. They show the customary strong pleochroism, with dark reddish brown absorption colors parallel to the basal cleavage, and yellow to very light yellow at right angles to this direction. The biotite in some of the specimens shows slight magmatic resorption with the development of fine magnetite grains (Spec. B62, B360). In case of some of the smaller biotite crystals there appears to have been a more or less complete replacement of the biotite substance by magnetite dust.

The plagioclase phenocrysts show alteration to sericite in some cases, or to mixtures of carbonates and chlorite in others. Some of the rocks appear to contain a little orthoclase and present a partial transition to the hornblende-biotite latite. This is true of the andesite shown on the map to the east of Kerber Creek, at the extreme southern boundary of the district (Spec. 62, B64, B360).

A particulary fresh looking and conspicuous outcrop of this biotite andesite is to be seen forming a cliff on a prominent point of the ridge that runs downward to the west from the Superior mine, on the south side of Rawley Gulch, and distant some 500 feet from that mine (Spec. B414). At this place the rock has a rather light gray color and shows abundant phenocrysts of plagioclase and also brownish black biotite one to two mm. in diameter.

Andesite Breccia—

Andesite breccias appear to be developed rather extensively in connection with the large andesite area shown in the east-central part of the map. In places the brecciated character of the rock is very marked, but more usually it is by no means easy to distinguish in the field between the massive andesite flows and the andesite breccias. The breccias have been so thoroughly cemented in connection with the alteration of the rocks of the district that the breccias have become as firm and solid as the massive rocks. The rocks vary in color from gray to green and brown. The component fragments are mostly small, an inch or less in diameter.

Under the microscope thin sections of these breccias show that the fragments composing them are of the nature of the augite andesite of the district. In composition, texture, and alteration products the fragments present all the varying types of the massive andesites. Naturally decomposition has progressed further in these fragmental rocks, but it has not succeeded in masking the original texture. The fragments of these beccias, it may be noted, appear to be of the same nature as those that occur so abundantly inclosed within the Bonanza latite.

Chemical Analysis—

A chemical analysis of augite andesite was made by Messrs. George Rohwer and Esbon Y. Titus in the chemical laboratory of the University of Colorado. This analysis, which is given below, was made on a sample of relatively fresh rock collected on the high point located 3,900 feet southwest of the summit of Round Mountain, map location B3. The rock is blackish gray in color. The phenocrysts consist of labradorite and rather sparingly developed augite. The groundmass shows plagioclase, otherwise only secondary minerals. The secondary minerals are chlorite, calcite and sericite.

ANALYSIS OF AUGITE ANDESITE

SiO_2	54.23	TiO_2	1.43
Al_2O_3	18.82	ZrO_2	trace
Fe_2O_3	1.69	CO_2	2.13
FeO	4.06	P_2O_5	.16
MgO	2.25	MnO	.17
CaO	6.62	Cl	trace
Na_2O	3.91	SO_3	trace
K_2O	3.08	S	trace
*H_2O—	.08		
‡H_2O+	1.51		
			100.14

*H_2O— = at 110°. ‡H_2O+ = above 110°.

Hornblende-Augite Monzonite

LOCATION AND MEGASCOPIC DESCRIPTION—

On the north side of Rawley Gulch, about one mile above the junction with Kerber Creek, and not over one or two hundred yards from the road, is a small area of a coarsely granular rock that presents a strong contract with the rocks surrounding it. A microscopic examination shows this rock to belong to the monzonite family, as, indeed, the hand specimen would also suggest. This plutonic outcrop is only a few hundred feet across and lies entirely surrounded by Bonanza latite, in close proximity to the augite andesite, which also underlies the latite at this point. This small monzonite mass lies close to the path of the deep drainage tunnel of the Rawley mine. The tunnel, which lies at a depth six or seven hundred feet below that of the monzonite outcrop, passes through only effusive rocks. It seems, therefore, that all the rocks surrounding this monzonite and the rocks below for a depth of at least 600 feet are latite or andesite. The monzonite is evidently a fragment floated off from some deep lying mass of monzonite during the eruption of the latite magma.

The rock is fairly coarse grained, of a grayish green color, and massive in texture. Greenish colored orthoclase and plagioclase, and a little bronze-brown biotite may be recognized under the lens.

Microscopic Character

Under the microscope this rock presents a coarse-grained, hypidiomorphic aggregate of orthoclase, plagioclase, colorless augite, light green and more or less fibrous appearing hornblende, a few irregular grains of reddish brown biotite, and accessory magnetite and apatite. Both orthoclase and plagioclase are abundant, the orthoclase occurring in rather large grains that often enclose more nearly idiomorphic grains of plagioclase.

The hornblende occurs in part as a selvage around the augite grains and, apparently, is an alteration product of the same. It shows a more or less fibrous appearance. The biotite is very fresh. It shows a brownish red color in rays that vibrate parallel to the cleavage, and a light brownish yellow at right angles thereto. Only two or three grains of biotite appear in a thin section. The feldspar is slightly sericitized.

REGIONAL METAMORPHIC ROCKS

Location and General Character

In several parts of the Bonanza district individual fragments of regional metamorphic rocks of varying character were found lying on or in connection with effusive rocks. Usually no outcrop of any extent was observed, so that such occurrences may be looked upon as fragments torn loose from the deep underlying crystalline rocks by the rising igneous magmas. But at the head of Squirrel Gulch may be seen on the map a considerable area of such rocks that most likely are a portion of the Archean floor through which the lavas broke, and on which they must rest. Perhaps the strongest reason for believing this is the fact that this area of crystalline rocks is exposed only at or near the bottom of the gulch.

Nearly a mile south of this area of regional metamorphic rocks, nearly opposite the saw mill in Squirrel Gulch, is another very much smaller patch of rocks. This small area may also be a portion of the Archean floor, or, perhaps with equal chance, a floated-off fragment.

Amphibolite

The large area near the head of Squirrel Gulch consists mostly of amphibolite. The rock is very massive, much resembling a diorite, of fine to medium grain, and of dark green to blackish green color. Under the microscope these rocks are seen to be composed of hornblende, quartz, plagioclase, orthoclase, also titanite and apatite. Magnetite is almost completely missing. The hornblende occurs in irregular or frayed grains and in smaller and more regular prisms and needles. The larger grains are more or less cellular and filled with enclosures of the other constituents of the rock. It is strongly pleochroic and shows the following colors: a, yellow; b, dark green; c, blue-green. The relative amounts of quartz and of the feldspars varies considerably in different specimens. In places the plagioclase may largely crowd out the other colorless minerals. Epidote is locally developed.

At certain places in this amphibolite area the amphibolite presents a remarkable brecciated structure. On the weathered surface the rock is seen to be composed of sharply angular fragments from one or two millimeters up to six inches in diameter, cemented by a grayish brown material. The structure is somewhat suggestive of the rhyoclastic structure described in these pages as characteristic of the Bonanza latite. On the fresh broken surface, however, there is hardly any difference to be seen between the fragments and the cement material. Under the microscope the fragments present about the same appearance as seen in the massive amphibolite described above. The material that fills the spaces between the fragments is also thoroughly crystalline. It is composed of green hornblende, green biotite, and leucoxene. The biotite is more abundant than the hornblende, and consists of very small and irregular grains. The dust-like particles of leucoxene give a clouded appearance to this material.

The origin of this brecciated amphibolite is uncertain. The amphibolite of this area is very likely a metamorphosed diorite. In this case the structure may very well by rhyoclastic, both the enclosed fragments and the enveloping igneous magma having subsequently been metamorphosed.

The small area east of the saw mill in Squirrel Gulch is also composed mainly of amphibolite essentially the same as that just described, except for the brecciated structure.

Muscovite-Biotite Schist

A portion of the area at the head of Squirrel Gulch is composed of a fairly fine grained, cleavable schist, in which both muscovite and biotite may be recognized under the magnifying lens. Under the microscope this rock is seen to be composed of granular quartz, plagioclase, orthoclase, greenish brown biotite and colorless muscovite. This schist was found in the northwestern part of the area of regional metamorphic rocks.

Pegmatite

Associated with the amphibolite rocks both of the large area at the head of Squirrel Gulch and of the smaller area east of the sam mill pegmatites were observed. In both cases they cut the amphibolite. A thin section of one of these disclosed a granular aggregate of quartz, plagioclase, and microcline.

SILICEOUS REPLACEMENTS

General Description

In connection with the description of the various ore bodies of the district frequent reference has been made to the presence of matasomatic replacement bodies. Such replacement is common enough in connection with the deposition of ore veins in mining districts as seen in the kaolinization or sericitization or silicification of the rock masses adjacent to ore veins. That silicification of the country rock has generally accompanied the deposition of ore in the Bonanza district has already been pointed out. But metasomatic replacement of the country rock has not been confined to the immediate vicinity of ore veins, as very extensive replacement has been observed at locations more or less remote from ore deposits. These silicious deposits may be distinguished as quartz and as jasper or chert replacements.

Quartz Replacements

As shown in Chapter IV quartz forms the principal gangue material of nearly all of the ore bodies of the district. While many of the veins may be considered to be of the nature of fissure fillings, almost invariably a quartz replacement of the rocks adjacent to the vein has taken place; and the gangue material that has been deposited in open fissures is so intimately intergrown with the replacement quartz that it is often difficult to make a sharp distinction between the two. In general, however, the replacement-quartz is much finer textured than the fissure-quartz. It is also inclined to be more or less cellular, with drusy quartz surfaces lining the vugs.

A microscopic examination of thin section of this replacement, as for instance, that of the Bonanza vein, shows a granular aggregate of large and small quartz grains that interlock in a very irregular fashion. Chalcedonic silica is entirely wanting, a feature that readily distinguishes the vein quartz from the jaspery replacements! Mixed sulphides are also to be seen scattered irregularly through the quartz mass.

Such quartz replacements form the ore veins in both Bonanza latite and augite andesite. The replacement is usually complete.

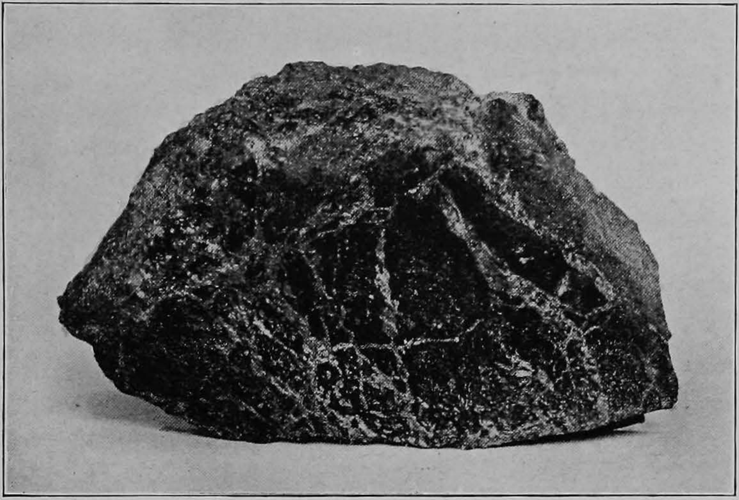
Jasper or Chert Replacements

Quite distinct from the above mentioned vein-quartz-replacements are those of a jaspery or cherty nature. These are very fine grained and uniform with a texture that may resemble flint, when very fine, or hornstone when somewhat coarser. In color they vary from grayish white or drab to a jaspery red or brown. They break with an extremely smooth, splintery, conchoidal fracture.

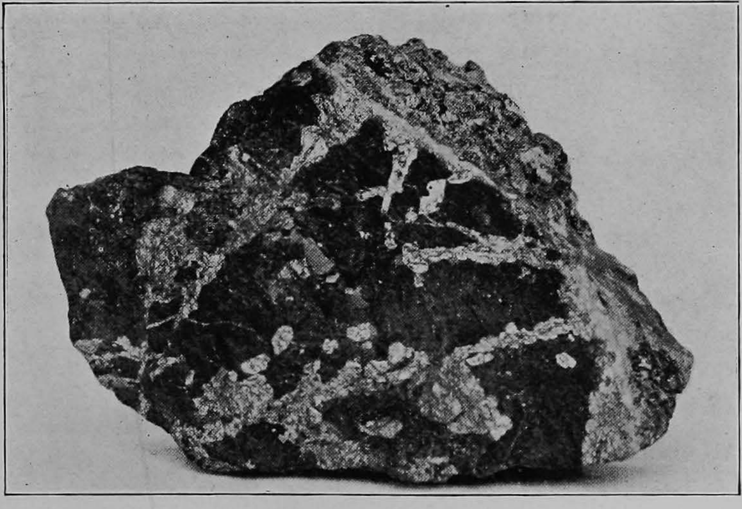
Under the microscope in thin section they are seen to be composed almost entirely of chalcedonic silica with little or no recognizable granular quartz. The chalcedony forms radially fibrous aggregates that usually occur in small sectors of spheres. The fibers show a negative elongation in most cases. But with these negative fibers there may occur a small amount of exactly similar material that have positive elongation. In both cases we have parallel extinction and an index of refraction less than that of the enclosing Canada balsam. These properties correspond with chalcedony, except in case of the positive fibers, which may perhaps be considered to be quartzine.

Such jasper masses may be entirely disconnected with any known ore veins. Such is true of a striking outcrop of this rock that stands up above the surface, after the fashion of many quartz veins, on the west side of the Villa Grove road, nearly opposite the mouth of Elkhorn Gulch. The rock at this place (Spec. B53) contains no pyrite or other sulphides.

Again this jasper may be found in conjunction with ore deposits, or in the vicinity of such deposits. In this case it is likely



A. Pyrite veinlets cutting replacement jasper, from the Rawley mine drainage tunnel. Three-fourths natural size.



B. Quartz veinlets cutting replacement jasper, from the Rawley mine drainage tunnel. Natural size.

to contain pyrite. Samples that came out of the deep drainage tunnel of the Rawley mine contain small sharp crystals of pyrite scattered through the mass or filling minute interlacing veinlets. As a general thing this material does not form the gangue of workable ore veins, although this appears to be the case in one of the veins in the St. Louis mine in Copper Gulch. It may, however, form one of the walls of a vein. It probably has been formed quite independently of the vein-quartz of the district, and its occasional association with ore bodies may be accidental.

These jasper replacements are not in the nature of locally developed nodules or narrow streaks. They have been formed on a large scale. As stated in Chapter IV, the Rawley drainage tunnel struck a body of this jasper three hundred feet thick. Samples collected from this body as well as from others show in thin section that the replacement of the original igneous rock is complete. No trace indicative of either the materials or texture of the original rock is to be seen.

The jasper or chert replacements occur in both the augite andesite and the Bonanza latite. (See Plate XVIII.)

STRUCTURAL AND HISTORICAL RELATIONSHIPS

RELATIONSHIPS BETWEEN THE LAVA FLOWS

In order properly to work out the relationships between the lava flows of this district it would be necessary to make an extended observation of the igneous rocks over an area many times that of the region under discussion, but, in the absence of such an extended investigation, certain points may be mentioned that throw more or less light on this problem.

That these rocks, with the exception of those that occur in dike form, were originally poured out on the surface as lava flows is indicated by the textures of most of the rocks, by the presence of glass or indications of its original existence, by the marked development of flow structures in the rhyolite and in the Bonanza latite, by the abundance of inclosed fragments in this same latite, and by the not infrequent development of amygdaloidal forms in the augite andesite. The extensive alteration of the rocks and the topographic features of the country prove, of course, that the lavas are not recent, but of great age. The present topography, in fact, is in no way directly due to the outpouring of the surface lavas, but solely to the effect of long continued erosion on a great series of igneous rocks, and to the removal of many hundreds and probably thousands of feet of rocks over the greater part of the territory.

As to the relative ages of the different flows the evidence is somewhat confusing, and even conflicting. Four of the main types of rock appear to have been formed in the following order, beginning at the bottom, or oldest: 1st, Augite andesite; 2nd, Bonanza latite; 3rd, Hornblende-biotite latite; 4th, rhyolite. This leaves the Eagle Gulch latite and the Hayden's Peak latite in an uncertain position. The above given order is based upon the positions of the augite andesite, the hornblende-biotite andesite, and the rhyolite with reference to the Bonanza latite. The last named rock has a marked flow structure that causes the rock to cleave readily parallel to the flow planes, and that gives the rock the appearance of a bedded deposit whose strike and dip can be measured. In most places the general direction of the dip can be seen, although the flow lines are not strongly enough developed to enable one to measure the strike and dip with much accuracy. In a number of places where the strike and dip could be satisfactorily determined they have been indicated on the map.

In the northern half of the district where these rocks are mainly developed the strike is approximately north and south and the dip westerly. Over the central portion of this northern half the dip amounts to forty or fifty degrees. In the northwest corner of the mapped area, where the rhyolite and hornblende-biotite andesite are developed, the strike and dip could not be definitely ascertained. The position of the hornblende-biotite andesite, outcropping, as it does, at about the same elevation on both the east and the west side of the ridge of which rhyolite forms the crest, would seem to be sufficient indication that these flows are approximately horizontal, and that the rhyolite is the younger. At a point a little north of the Rawley Gulch road, at map location E4, occurs a bedded series of augite andesite, amygdaloidal augite andesite, and an interbedded sheet of Bonanza latite a few feet thick—not shown on the map. This bedded series shows a westerly dip of about 17°.

As is well known, the flow planes of a surface lava are often very irregular and may in places dip in various directions or even be folded and contorted. Such contortion of the flow planes is very pronounced on the southwest side of East Porphyry Mountain (see Plate IX, Fig. B). But in case of the Bonanza latite the flow planes are usually fairly free from local fluctuations and have a very persistent westerly dip. These flow planes undoubtedly were horizontal or nearly horizontal at the time of the outpouring of the lava stream. Their present tilted position is due to subsequent movements of the earth's crust at this point.

In the southern portion of the district the bonanza latite appears to have been folded into a synclinal arch. The axis of the fold is approximately north and south. West of this arch the flowage planes dip to the west, and east of it to the east. The Eagle Gulch latite and Hayden's Peak latite show no bedding or flowage planes so that no dips or strikes could be measured.

As already stated, the evidence as to the relative ages of the four igneous rocks that cover the northern part of the district is somewhat confusing and contradictory. This is due to the presence of dikes or apparent dikes cutting the lava flows. Within the Bonanza latite area may be seen a number of dikes of augite andesite. The rock of these dikes does not appear to be essentially different from that of the main andesite mass. Yet the dikes that cut the latite are necessarily younger than the latite, whereas the main augite andesite flows are shown by their position to be older than the Bonanza latite. Probably both these statements are true and are to be explained on the not unlikely supposition that the main augite andesite mass developed on the east side of the mapped area of the Bonanza district is only part of a succession of similar outpourings, some before and some after the eruption of the Bonanza latite magma. The dikes cutting the Bonanza latite are to be considered to be genetically connected with augite andesite flows of later date. A more extended study of the surrounding region would very likely furnish evidence of such later andesite flows.

To the south of Round Mountain may be seen a dike-like extension of the Bonanza latite running out into the augite andesite. The evidence at hand is not sufficient to convince the writer that this is really a dike. It lies on the surface of the territory covered by the Rawley and Antoro mines. If it is a dike it could hardly fail to be found in the workings of these mines. Yet no rock was observed in connection with the underground workings of the Rawley and Antoro mines that could be identified as Bonanza latite. It is not, however, necessary to assume that this long strip of Bonanza latite is a dike cutting the andesite. As its direction approximately corresponds with the strike indicated on the map for the bedded andesite to the east, it may be due to a slight infolding of the latite into the andesite along a synclinal-fold axis. In other words it may be remnant left by the erosion of the overlying latite sheet.

THICKNESS OF THE IGNEOUS ROCKS

There is little evidence of a positive nature as to the actual thickness of the igneous series as a whole. As stated in Chapter IV, however, there is reason to believe that the small area of regional metamorphic rocks at the head of Squirrel Gulch are a part of the floor or surface on which the lavas were outpoured. On this assumption, therefore, the series of lava flows is much thinner on the north end of the district than elsewhere. In estimating the thickness of the volcanic series it is not necessary to assume that the lavas poured out on a level floor. It is quite possible that the surface was far from level and may have been as diversified as the present surface of this district. Furthermore, even though the surface may have been level at the time of the eruption of lava, it would necessarily share in any subsequent foldings or disturbances of the earth's crust to which the lavas themselves have been subjected. It is impossible, therefore, to come to any conclusion as to the thickness of the igneous rocks that is based on very definite evidence. But as none of the deeply cut gulches of the district, with the exception of the upper end of the Squirrel Gulch, have cut through to the underlying formation, it is reasonable to assume that the lavas extend some distance below the bottom of these gulches.

Further than this, we know that the deep drainage tunnel of the Rawley mine cuts the Rawley vein at a depth of 1,200 feet below the surface and at no point in its course penetrates the underlying Archean formation. For the district immediately to the north of the end of this drainage tunnel, that is, for the high ground lying between Round Mountain and the Antoro mine, we may reasonably add at least another thousand feet to the 1,200 feet proved to exist at the Rawley mine. Probably the same is true of the high ground to the south of Rawley Gulch. Twenty-two hundred feet, therefore, may be taken as the minimum probable thickness of the igneous rocks for the high ground around the upper end of Rawley Gulch. They may, of course, be, and probably are, considerably thicker than this minimum.

As to the thickness of the igneous for the southern and south-eastern portion of the Bonanza district, there is very little evidence. But there is nothing to indicate that it is any less than above indicated.

AGE OF THE IGNEOUS ROCKS

A mile or two to the east of the area covered by this report sedimentary rocks are said to occur, although they were not investigated by the writer. There are, however, undoubtedly the same series of rock formations that occur on the road from Bonanza to Villa Grove, about midway between these two towns. The sedimentary rocks as they occur on both sides of the Kerber Creek valley at the point just indicated consist of sandstones, grits, shales and blue-gray limestone. In the shale a somewhat graphitic seam of coal some two to three feet wide has been and worked to a slight extent. These sedimentary rocks have been mapped by the Hayden survey as Carboniferous. They lie directly upon the Archean, which at this point consists of granite gneiss and biotite geniss.

About nine miles below Bonanza in the Kerber Creek valley the igneous rock come to an end and are seen lying directly on the Archean. About a quarter of a mile to the east of this place the Bonanza latite occurs in the form of a dike cutting the Carboniferous formation. It forms a very marked isolated hill, with nearly vertical southern face, on the north side of the Villa Grove road. Back of this Bonanza latite occurs an augite andesite, whose relations to the latite are not clear. From this evidence it is plain that the period of eruption of the igneous rocks is post-Carboniferous. But there is no evidence to indicate at what period subsequent to the Carboniferous the eruption occurred. As already stated these volcanic rocks are undoubtedly genetically connected with the great Tertiary volcanic eruptive series of the San Juan mountains and of the same age. Just where they belong in this series may later be determined by a study of the formations that lie between.

FAULT AND VEIN-SYSTEMS

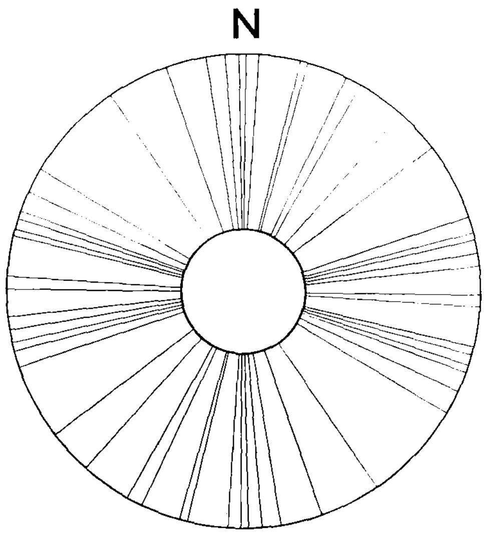
While minor faults involving a movement of a few inches or, at most, a few feet are of common occurrence, no evidence of faulting on a large scale has been discovered. Quite possibly the absence of such evidence may be due to the comparatively small development work that has been done, or to the character of the rock formations which, because of their uniformity, make it difficult to determine the direction and amount of fault movements.

So far as known, the most pronounced line of faulting is that of the Paragon Fault which is known to throw the Rawley vein. Here again the extent of the movement is unknown, but is supposed to be considerable. As already stated, the Paragon fault is a fault-zone of fifty feet or more in width. Similar faults will doubtless be disclosed should there be any very considerable mining development undertaken in the district.

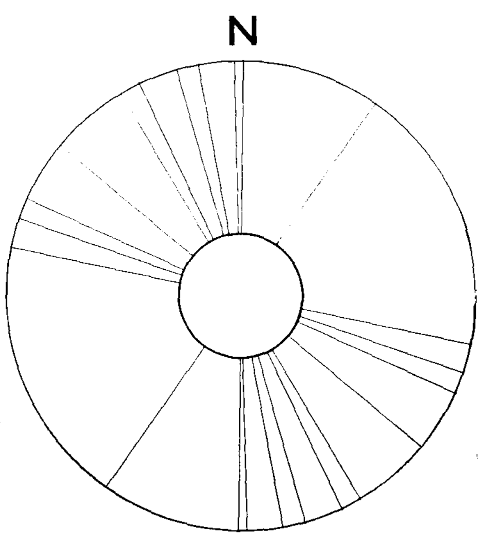
Attention has already been called to the fact that many of the veins of the Bonanza district are fault-veins. That is, fault movements have taken place along the vein, often producing a slickendiding or a clay gouge along one or both walls. But this is by no means universal. Minor faults cutting the vein in a direction that does not conform to the strike and dip of the vein is of common occurrence, as is also the presence of veins that are not accompanied by faulting.

Plate 19, Fig. A, shows the direction of the vein-strikes of the district so far as their direction was recorded. It will be noted that, while the veins strike in pretty much all directions, there is a pronounced tendency towards an east-west strike, and a somewhat less pronounced tendency in a north-south direction.

As to the prevailing direction for fault-strikes this may be seen from an inspection of Plate 19, Fig. B. To a very surprising extent the faults of the district have strikes that lie in the northwest-southeast quadrants. While a few of the faults here recorded are those of fault-veins, most of them are independent of veins.



A. Represents the directions of observed vein-strikes in the district.



B. Represents the directions of the observed fault-strikes in the district.

CHAPTER IV

ECONOMIC GEOLOGY

INTRODUCTION

In a general way the ore deposits of the Bonanza district are often referred to locally as forming a northern zone, characterized by lead-zinc-silver ores, and a southern zone in which gold-copper ores abound. Both of these zones have a general northeast-southwest direction. The boundary between the two is not sharply drawn, but, roughly speaking, the northern one may be said to lie along both sides of Rawley Gulch and the region lying north of this up to Round Mountain and on the upper Kerber Creek. The southern zone lies south of this limit.

Aside from this double division of the district a further division is customarily referred to as the ''Manganese belt.'' This lies mostly in the extreme southerly part of the district, in Eagle Gulch and further south beyond the bounds of the mapped area. This manganese belt will be treated separately after discussing the above mentioned lead-zinc-silver and gold-copper ores.

This division into two zones does not, however, seem to be justified by any very marked difference in the character of ores involved. The distinction is based more on a difference in relative amounts of the different minerals present and on the relative values of gold and silver, especially on the latter, than on a difference in kind of minerals. Certain mines in Copper Gulch, for instance, were found to carry much higher values in gold than was the case in the mines of the more northern parts of the district. As to the actual minerals that compose the ore-veins, with, perhaps, one or two exceptions, there does not seem to be a great difference between the various mines and prospects in the northern and southern zones or in different parts of the same zone.

GANGUE MINERALS

The minerals forming the gangue are quartz, barite and rhodochrosite. The last named mineral is so rare, except in the above mentioned manganese belt, that it does not call for more than passing mention. Barite, while far from universal, nevertheless occurs with great frequency. It is, however, very irregularly distributed, fluctuating greatly within the same vein, or occurring in one vein and being absent from another vein of the same mine. Even where most abundant it is distinctly subordinate to quartz. Its color is white, about like that of milk-white quartz. It occurs in platy masses and is easily recognized by its characteristic cleavage, also by its weight wherever it is abundant.

Quartz fluctuates considerably as a gangue mineral. Milk-white vein-quartz—"bull quartz" of the miners—is not very common. Usually the quartz is finer grained, or is irregularly grained and streaked in its color, darker and lighter shades of white or of whitish gray being in evidence. These variations are such as customarily occur in case of replacement quartz. As will be noted later, most of the quartz owes its origin to a metasomatic replacement of the country rock. Where this rock has been subjected to a brecciation, as is very frequently the case, the replaced rock fragments have left traces of their outlines in the varying structure and coloring of the quartz. Vugs lined with more or less clear quartz crystals of small size are by no means rare, but they do not characterize the ore.

Quartz in the form of jasper is extraordinarily abundant in some parts of the district. It is not always or even usually present as the gangue material of the veins, but in some cases it does form the gangue. This is particularly true of the St. Louis mine and of parts of the Rawley mine. In the former case it appears to be associated with very rich ore. This jasper has been more particularly described in Chapter III. Suffice it to say its color is brownish or reddish, it is the product of siliceous replacement of the country rock on a large scale, and it is often more or less impregnated with pyrite crystals.

ORE-MINERALS

With the exception of the minerals of the oxidation zone, none of which were in evidence at the date of examination, the ore minerals of the camp consist of pyrite, galenite, sphalerite, gray copper and chalcopyrite; also occasionally bornite, enargite, chalcocite and the tellurides of gold, silver and copper, and native silver.

In a few cases, especially at the Empress Josephine mine in Copper Gulch, gold and silver are to be found in recognizable tellurides, or the silver, as at the Eagle mine, in the form of wire silver. Usually these precious metals occur in unrecognizable form, enriching the baser sulphides.

Copper is rarely present as chalcopyrite, and still less commonly as enargite and chalcocite. Its more common form is that of gray copper, which usually is very rich in silver. A good instance of this is to be found in the Shawmut mine on Round Mountain. Enargite and chalcocite were noted only at the Rawley mine, but undoubtedly do occur at other mines in the lower levels.

ORE-VALUES

As may readily be understood, the ores of Bonanza must have run fairly high in the early days to have justified shipping. And the same to some extent is true today. Very little ore has been subjected to concentration. The so-called Bonanza mill, which is more particularly described elsewhere, has been running a comparatively short time and has not been able to treat a large amount of ore. But very little attempt, therefore, has been made to develop concentrating ore bodies. While there is undoubtedly much concentrating ore available, very little has been shipped and, with the exception of the Rawley mine, but little development work has been done on such ores. Statistical information available is fragmentary and not fully reliable and is confined to shipping ores.

Mr. J. P. Poole of Bonanza has made as careful an estimate as possible of the output of the more important properties for the period 1881 to 1900, which practically covers the producing period of the camp. The comparatively small amount of ore that has been produced since that date will probably not greatly add to the total values given. This estimate is based as far as possible on reports and documents to which Mr. Poole had access in 1900, the year in which the estimate of the output of the camp was made. Mr. Poole has kindly allowed the insertion here of his estimate.

Table showing the production of mines in the Bonanza District from 1881 to 1900:

Mine	Ore	Value per ton	Tons	Total
Antoro	Au.Ag.Pb.Cu.	$50	1,000	$50,000
Atlantic	Au.Ag.Cu.	50	50	2,500
Arkansas	Ag.Pb.	50	100	5,000
Bonanza	Ag.Pb	150	2,000	300,000
Boss Mammoth	Au.Ag	75	500	37,500
Columbia	Au.Ag.	30	350	10,500
Cora	Au.Cu.	35	200	7,000
Colorado Bell	Ag.Pb.	25	100	2,500
Cornucopia	Au.Ag.Cu.	78	100	7,800
Colorado	Ag.Pb.	40	20	800
Deming	Ag.Pb.	25	30	750
Enterprise	Au.Ag.Pb.	50	25	1,250
Eagle	Au.Ag.	100	1,500	150,000
Exchequer	Au.Ag.	125	500	62,500
Erie	Au.Ag.Pb.Cu.	40	600	24,000
Evening Star	Au.Ag.Pb.	40	100	4,000
Empress Josephine	Au.Ag.	60	5,000	300,000
Elra	Au.Ag.	50	30	1,500
First Chance	Au.Ag.Pb.	40	100	4,000
Great Mugul	Au.Ag.Pb.	40	40	1,600
Hortense	Au.Ag.	40	50	2,000
Hanover	Ag.Pb.	25	700	17,500
Hawk	Au.Ag.	100	100	10,000
Insurance	Ag.Pb.	60	40	2,400
Jupiter	Ag.Pb.	30	40	1,200
Keystone	Ag.Pb.	50	100	5,000
Little Jenny	Ag.Pb.	25	500	12,500
Little Manitou	Au.Ag.Cu.	50	50	2,500
Legal Tender	Au.Ag.Cu.	40	100	4,000
Little Kittie	Ag.Pb.	40	20	800
Minnie Lynch	Ag.Pb.Cu.	40	60	2,400
Michigan	Ag.Pb.	35	700	24,500
Now What	Ag.Pb.	30	30	900
Occidental	Ag.Pb.	40	50	2,000
Payson	Ag.Pb.	30	1,000	30,000
Radcliff	Ag.Pb.Cu.	40	40	1,600
Rawley	Au.Ag.Pb.Cu.	30	500	15,000
Revenue	Ag.Pb.	30	40	1,200
Sosthenes	Au.Ag.	100	400	40,000
Superior	Ag.Pb.Cu.	40	100	4,000
Shawmut	Ag.Pb.Cu.	60	700	42,000
Saint Louis	Au.Ag.	60	60	3,600
Saint Joseph	Au.Pb.	50	30	1,500
Whale	Au.Ag.Cu.	50	2,000	100,000
Wheel of Fortune	Ag.Pb.	40	100	4,000
Wide Awake	Au.Ag.Pb.Cu.	50	30	1,500
Yellow Type	Au.Ag.	100	10	1,000

MINES IN RAWLEY GULCH

THE RAWLEY MINE

Location

The most promising mine of the district is the Rawley mine owned by the Rawley Mining Company and controlled by New York capitalists. The development of this property is almost entirely confined to the Rawley vein, an east-west striking vein that lies to the north of Rawley creek, at a point about two and a half miles by wagon road from Bonanza. Although the ore of this vein is comparatively low-grade, its demonstrated extent and width are such as to have justified a very considerable outlay for development work. The mine is located at the bottom of Rawley Gulch at an elevation of approximately 10,650 feet.

History and Development

Ore was first discovered about 1880, and from that time down to about 1902 or 1903, when a group of claims including the Rawley claim was purchased by those now controlling the property, considerable money was spent in developing the mine or in the erection of mills. It is not definitely known whether any ore was worked at a profit. This may well be doubted owing to the fact that the nearest railroad station was at Villa Grove, distant over eighteen miles, and the grade of the ore could hardly have justified shipping to so distant a point.

At present there is a mill capable of handling one hundred tons a day. This was erected about 1903, but did not prove successful, quite possibly due to the fact that the water in Rawley Gulch is very fluctuating and, for the greater part of the year, is not sufficient to run the mill at capacity.

In 1911 the company started to drive a long drainage tunnel with a view to cutting the Rawley vein at a point some 1,200 feet below the surface, and 600 feet below the lowest workings of the mine. This tunnel was located under the name "High Rock Tunnel," and as such it is indicated on the map in the Surveyor General's office. It is now called by the Rawley company the "Rawley No. 12 tunnel." It will be more convenient in this paper to refer to it under the name of drainage tunnel. The driving of this tunnel and the reasons that led the company to attempt it are described in an article by F. M. Simonds and E. Z. Burns,[1] consulting engineers of the Rawley Mining Company. Further facts concerning the driving of this tunnel are given in a paper by Will C. Russell,[2] General Manager of the mine. As the problems involved in driving this tunnel and the information obtained of the country rock and of the Rawley vein are of general interest to all who have interests in the district, the writer will take the liberty of drawing freely from these two papers, and in so doing wishes to acknowledge his indebtedness to the parties named. So far as the remainder of this section on the History and Development of the Rawley mine is concerned, it will be understood that it is taken from these two papers and is partly directly quoted from the same.

In discussing the problem that the company had undertaken to solve, Simonds and Burns state that

"The question which then confronted the owners was, briefly, whether to abandon the enterprise as a total loss, or to pursue a course of systematic development of the ore body as exposed by three short drifts."

"Without committing themselves to an extensive policy of development, the stockholders finally decided to do a small amount of development work—to put some money into the ground. Almost from the start, this work showed encouraging results in the way of blocking out ore of satisfactory grade, although it was conducted during the next few years under many discouragements. Besides the natural difficulties of doing work at such a distance from the railway, there were frequent labor disturbances, causing a shut-down, in one instance, of nearly two years. This brings us to 1910, at which time we had proved the vein to a depth of 600 ft., and had developed on 'blocked out' and 'probable' ore a gross value of about $5,000,000. We found that the water was increasing at the rate of about 100 gal. per min. for each 100 ft. of added depth. Also we found the character of the ore had changed .... from a silver-lead-copper concentrating-ore in the upper levels, to a semi-pyritic silver-copper ore on the sixth level."

"In view of the altered problem of mining and treatment which this new condition presented, we concluded that it would be very desirable to block out a large tonnage of this silver-copper ore, in order, first, to prove the average character of ore to be encountered with depth, and, second, to obtain ore to which the silver-copper concentrates derived from the silver-lead-copper ore of the upper levels could be added and more economically treated."

In connection with the investigation of the conditions confronting the company it further appears that

1. A Problem in Mining, together with Some Data on Tunnel-Driving, Bull. Am. Inst. Min. Eng., No. 75, March, 1913, pp. 369-402.

2. Driving a Long Adit at Bonanza, Colorado, Eng. and Min. Jour. Vol. 95, No. 5, 1913, p. 272.

"Surveys showed that the property was only about 6.5 miles in an air-line from a point on the railway at which an adequate water supply was found. According to careful estimates, Rawley ore could be handled at a good profit on a scale of from 200 to 300 tons a day to this point, and the ore blocked out above the sixth level would net considerably over $1,000,000."

"Surveys showed also that a tunnel some 6,200 ft. long would intersect the Rawley vein (if it were there) on the 12th level, 600 ft. below our lowest workings."

Owing to the very great and increasing cost of sinking a shaft where so much water had to be handled it was finally decided to drive the proposed tunnel with a view to cutting the vein at the 12th level. On Plate —, opposite page —, will be seen the extent of development of the mine at the time the tunnel was started, and also, it may be added, the conditions still holding. The figure represents a vertical section along the course of the Rawley vein, which also is nearly vertical, and shows work has been done on six levels, three of them above the level of the creek and worked through tunnels, three below the creek level and worked through a shaft sunk from the third level. The underground workings in these six levels amounts to a total of 7,416 feet. The position of the tunnel is shown 600 feet below the sixth level, also a zone of faulting that will be referred to in a later section.

The portal of the tunnel was located in Squirrel Gulch a little over half a mile above the junction of Squirrel Creek with Kerber Creek. The length of the tunnel from the portal to the point where the tunnel intersected the Rawley vein is 6,212 feet. Actual work at the portal was begun on May 7th, 1911, and the tunnel reached the vein on October 23rd, 1912.

The following quotations from Mr. Russell's paper will give a good idea of the conditions under which the tunnel was driven, of the equipment used and of the methods employed:

"The work of driving this tunnel, which is 7 by 8 ft. in the clear, running principally through altered andesite and at about a right angle to the vein system, covered a period of 17 months and 12 days. The rock varied greatly in hardness and friability, it having been necessary to timber a total of 1618 ft. As an indication of the irregularity of the formation, it may be said that in April, 1912, only 40 ft. were driven, while in August, 1912, the adit was advanced 555 ft. in 26 days of drillings, the remainder of the month having been given up to timbering."

EQUIPMENT USED.

"In the work of constructing the new tunnel, there were consumed 41 tons of 16-lb. rails, 38 tons 241 lb. of powder, 33,819 caps, 51 miles of fuse, and a little over 2,000 cords of wood. A steam plant of 120 hp. capacity and an Imperial type 10 Rand compressor furnished the power, while the workings were ventilated by a No. 3 Roots suction blower, directly connected with a 9x9 in. high-speed, upright engine."

"Slip-joint pipe, 12 and 13 in. in diameter, of No. 18 iron, riveted and dipped, was used in connection with the blower, while the compressed-air pipe ran from a maximum of 6 in. down to 3 in. in diameter at the heading. Three air receivers, 42 in. in diameter by 10 feet in length, were placed at intervals of about 2,000 ft. in the tunnel. In the blacksmith shop there were used a No. 8 Bradley coke furnace for heating the drill steel and a No. 2 Leyner pneumatic sharpener, drop hammer, etc. For the purposes of the tunnel construction alone a camp of 14 buildings was erected. A total of 40 all-steel cars of 17⅓ cu. ft. capacity each, and six animals were used for hauling the muck. The normal crew in the heading consisted of a shift boss, two machine men, two machine helpers, two trammers and a pipe-and-track man."

ROUTINE OF WORK.

"Two machine drills of the No. 8 water Leyner type, carrying 1¼ in. hollow steel, were used on each drift and were mounted on a 7-ft. crossbar for the bottom set-up. Three hangers set into hitches in the ribs at the roof, held the air and water hose in the clear. No. 44 square-pointed shovels were used to remove the muck from heavy steel plates, which covered the floor from rib to rib and extended 30 ft. from the face."

"At the beginning of the operation two shifts, drilling 7- and 8-ft. rounds were maintained, but later on it was found that three shifts drilling shorter rounds produced better average results. During the operation of removing the muck, the machine men drilled the top, and in ordinary ground the muck was removed by the time the machine men were ready for the lifters. According to the requirements of the ground, 8x8-in. and 10x12-in. timbers, were installed, mud sills being laid wherever full tunnel sets became necessary. Most of the timbers were peeled and hewed, these being considered superior to sawed material."

"A ditch 1 ft. in depth and 2 ft. in width, dug along the right rib and under the mud sills, carried off the water. The ventilation, compressed-air and machine-water pipes were set on cross ties over the ditch, while the track was placed on the opposite side of the tunnel. A grade of 6 in. to 100 ft. was adopted, all the timbers being lined and graded with instruments."

"In the operation of driving, hangers suspended from plugs in the roof were used to give the center line, and the grade of the track. At every survey station the grade was taken and corrected, and upon completion of the 6235 ft. a check leveling showed the breast to be a little over a foot above schedule, this rise having been due to the difficulty in laying sills in flooded and running ground. After considerable experimenting it was found that 40 per cent dynamite was the most efficient explosive day in and day out. The entire cost of the adit was $123,920, or $19.87 per ft."

According to Simonds and Burns the working force used in driving this tunnel was organized as follows:

	Rate of wages per day
One superintendent, One surveyor-bookkeeper,	
One foreman	$6.00
One shift boss per shift	5.00
Two machine men per shift	4.00
Two machine helpers per shift	3.75
Three to four muckers per shift	3.50
One swamper per shift	3.00
One to more pipe- track- and ditch men, as required	3.50
One trammer per shift	3.50
One blacksmith	4.50
One head mechanic	4.50
Two power-house men (two shifts)	4.00
One car-greaser, dump, and powder-man per shift	3.00
One wood-hauler	3.00
Timber-framer, as required	4.00
One roustabout	3.00
One cook and helper.	

The zone of faulting that is mentioned above as cutting the Rawley vein was intersected by the tunnel at a point a little over 3,910 feet from the portal and caused much delay because of the flood of water let loose. Describing this incident, Simonds and Burns say:

"This sudden influx of water was interesting, but very expensive. About Mar. 25 we struck the zone of faulting .... In this zone the rock is full of slips and very much ground up. The tunnel was perfectly dry for a distance of about 40 ft. in this formation. On Mar. 29, a round of holes was put in, the bottom of each hole being perfectly dry. When this round was fired a flood of water came with it. The ground-up material of this formation seemed to distintegrate in contact with water and filled the entire face of the tunnel. It was roughly estimated that the volume of water amounted to more than 1,000 gal. per min. After trying in vain to catch up the ground at the face, the Superintendent came back about 50 ft. in the tunnel, and started a cross-cut at an angle to encounter the water some distance from the face, and thus divert the flow, or most of it, from the main tunnel. This plan succeeded; enough water was diverted to enable us to proceed with the driving of the main tunnel, although for many weeks it was only with the greatest effort that any progress whatever was made."

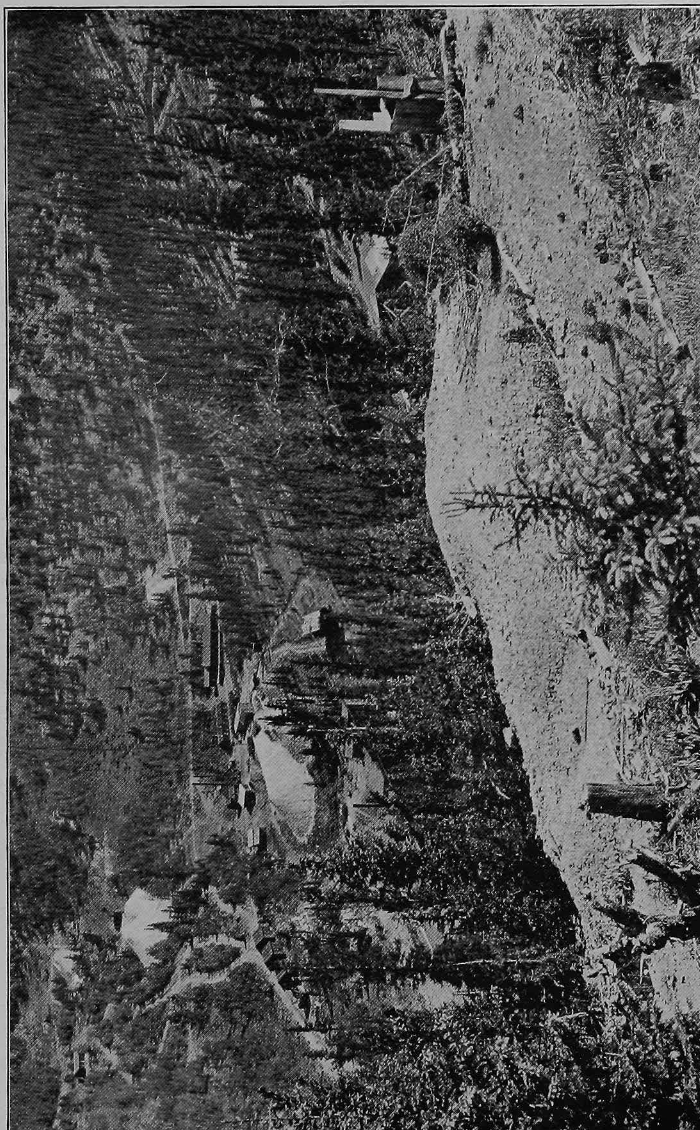
In deciding to drive this tunnel the company assumed the risk of finding the vein at a depth 600 feet below the lowest mine working, for there was no positive evidence that the vein continued to that depth, or, if so, that the vein would carry values. There was also no assurance that the cutting of the vein at that depth would unwater the workings above. It was a matter of gratification for all concerned, therefore, that the vein was struck six feet strong, and that, with the cutting of the vein, there came a rush of water that completey drained the mine workings above in 38 days.

The successful driving of this tunnel and the consequent proof that the Rawley vein continues at least to the twelfth level, or six hundred feet below the lowest mine workings, and the further evidence to the effect that the values of the vein are greater at the tunnel level than they are above, reveal a much greater ore body and a more profitable one than could otherwise have been figured on. It would seem, therefore, as though the way were now open for the development of a great property. So far as the public are informed, however, up to this date, January, 1915, nothing further has been done in the development of the mine.

Rock Formations in Mine and Tunnel

Owing to extensive mineralization and subsequent further alteration of the rocks adjacent to the Rawley, and exposed in the mine workings, it is not always possible to distinguish variations in the character of the rock unless such variations are strongly marked. The rocks at the surface of the mine are andesite, and probably such is also the rock throughout the mine workings. So far as known the Bonanza latite that appears on the surface over part of the mine in the shape of a long, narrow northeasterly trending strip, does not appear in the mine.

The portal of the drainage tunnel is located on the Bonanza latite, and for some distance, not definitely determined, the tunnel continues in this same latite, but the greater portion of it runs through andesite. From a study of the dump at the portal of the tunnel one can gain a good idea of the different types of rock through which the tunnel runs. These represent andesites of greatly varying appearance. The fresher varieties are very dark in color, almost black, and are often fine grained rocks with numerous but minute and inconspicuous feldspar phenocrysts. Other varieties are coarser grained and conspicuously porphyritic. Still others are scoriaceous or amygdaloidal, being evidently portions of surface flows. It is evident that the andesite through which the tunnel runs and which has a thickness at the mine of not less than 1,200 feet, is not one homogeneous rock mass, but is composed of several and perhaps many superimposed lava flows



Buildings of the Rawley mine in Rawley Gulch that were originally poured out on the surface.

Nowhere is the andesite exposed in mine or tunnel entirely fresh. Even the freshest looking pieces disclose under the microscope, as is shown elsewhere, more or less alteration. In very many cases, however, the alteration is far advanced and even complete. This more extensive alteration often takes the form of complete rotting through the kaolinization or sericitization of the rock mass. Such alteration usually accompanies faulting of the rock on a greater or less scale.

Very commonly the alteration takes the form of silicification. In this case the silica is in cherty or jaspery form, such as often is to be seen associated with some of the ore veins of the camp. This cherty material represents a replacement of the original andesite which very likely took place in connection with the formation of the mineral veins. Usually the color is brownish or reddish and may, therefore, very properly be designated as jasper. It occurs in a number of places in the tunnel. At a point about half a mile from the portal a continuous mass of this material 300 feet wide was struck. It is very common to find pyrite disseminated through the chert. This may occur in small, sharply defined crystals having the shape of the pentagonal dodecahedron, or in grains, and may make up one-third or more of the mass. In places the chert has been brecciated or, perhaps, simply fractured. In this case the pyrite occurs in continuous streaks along the fracture lines so as to form a network of interlacing veinlets, the metallic veins showing up in strong and beautiful contrast with the reddish jasper. This jaspery rock proved to be very difficult to drill on account of the rapidity with which it would take the edge off the drill. Plate 15B shows tunnel portal.

Vein Systems

THE RAWLEY VEIN—

There are two independent vein systems represented in the Rawley mine. These are seen in the East-West striking Paragon fault or vein and in the North-South striking Rawley vein. Although some workable ore is said to have been found in the Paragon vein, the main ore body of the Rawley mine is the Rawley vein. This vein is very well exposed in the mine. At the time it was examined, access could not be had to the two lower levels, as they were filled with water and observations had to be confined to the four upper levels. Altogether six levels have been opened at vertical distances of 100 feet. The four upper levels have been worked through tunnels or adits. The two lower levels, being below the creek level, were worked through a shaft, or, more properly, a winze that runs from the third level to the sixth.

The Rawley vein fluctuates considerably in strike which has a general north-west direction, deviating as much as 20° to the west of north. It is nearly vertical, the dip being 85° E. The vein occupies a line of fracturing and faulting, and may properly be called a fault-vein. There is, however, replacement of the wall rock, or, better, perhaps, of the broken and more or less crushed rock material that lies between parallel running fissures. The walls are usually plainly developed. A clay gouge may usually be seen either along the hanging or the foot wall, in most places along the east or hanging wall. The vein is very strong and varies in width from two or three feet to twelve or more feet. While necessarily fluctuating in richness and in the relative amounts of gangue and ore-minerals, the vein is upon the whole unusually uniform from wall to wall. The ore does not run in narrow streaks as is often the case in wide veins.

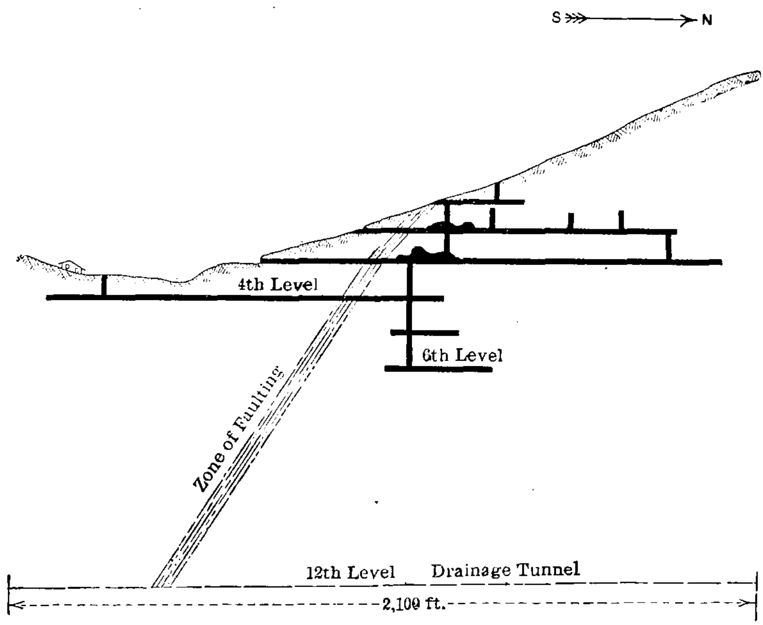


FIG. 1.—SECTION ON THE VEIN OF THE RAWLEY MINE.

Altogether in the six levels of the mine about 4,000 feet of drifting has been done on this vein. As is shown elsewhere, the

Paragon fault cuts and faults the vein so that the vein lies partly on the north and partly on the south side of this fault. So far as the mine workings show the portion south of the Paragon fault does not carry values to amount to much. All the drifts north of this fault are in ore. Of the 4,000 feet of drifts about 2,600 feet lie north of the Paragon fault and are in ore. The longest of these ore-drifts is on the third level and measures approximately 900 feet. This figure represents, therefore, the length of the ore vein so far as shown by the mine workings. If, however, the Paragon fault continues in the depth to form the southern boundary of pay-ore, the length of the workable portion of the vein at the level of the drainage tunnel, as shown by Fig. 1, must be considerably more than 900 feet.

THE PARAGON FAULT AND VEIN—

As stated above, the Rawley vein is faulted by the Paragon fault. Where it crosses the Rawley vein it strikes approximately east and west and dips 55° to the south. It is a fault zone some fifty feet wide, the rock between the walls being greatly crushed, sheared, and rotted. At the time of examination this fault was not well exposed on account of the caving in of the soft ground. It is evident that the fault is younger than the Rawley vein, but the amount and direction of the faulting could not be seen. On this point Simonds and Burns[1] state that

> "The lateral throw of this fault was slight, if any, but there is reason to believe that the vertical throw must have been considerable. However, no definite data existed at the time, and only meager data have since developed to indicate the amount of this vertical displacement. There being but little lateral throw, the alignment of vertical or nearly vertical veins was only slightly disturbed by this faulted zone."

From the description of the Paragon fault given elsewhere it will be seen that the fault carried in places ore values. To some extent this is said to be true at the Rawley mine. Quite aside from the possibility of this fault carrying ore, a certain amount of drag ore is to be expected where the fault crosses the Rawley vein.

The Rawley Ore

ORE- AND GANGUE-MINERALS—

The ore body of the Rawley vein contains an unusually great variety of minerals. These may be grouped into gangue-minerals,

1. Op. cit. p. 371.

or those that carry no metallic elements of commercial value, and ore-minerals, or those that carry such valuable elements.

Gangue-Minerals—	Ore-Minerals—
Quartz	Pyrite
Jasper	Sphalerite
Barite	Galena
Rhodochrosite	Chalcopyrite
Siderite	Tennantite
Calcite	Bornite
	Enargite
	Chalcocite

Gangue-Minerals—

Of the six minerals given above in the list of gangue-minerals the last four play a very inconspicuous part and are to be found only in the small vugs that abound in this ore. Quartz or, locally, jasper, forms the great bulk of the vein. As the quartz occurs mostly as a replacement product of the andesite it seldom occurs in the form of pure white masses, and even narrow streaks of such quartz are not common. It usually occurs in grayish or whitish, granular masses more or less intimately impregnated with pyrite and other sulphides, and containing numerous small vugs lined with small quartz or with both quartz and sulphides. The jaspery or cherty variety of quartz does not appear to occur very extensively in this vein. It is quite possible that it may be met with in the rock adjacent to the vein proper. Quartz also occurs somewhat sparingly as pseudomorphous replacements of barite crystals or, possibly, of other gangue-minerals.

The other gangue-minerals occur rather sporadically and appear to be confined to the vugs. The most abundant is barite which seems to be more sparingly developed than is the case with most of the veins in the Bonanza district. It is white and tabular with the tablets assuming rhombic form, owing to the development of the prism. Pink or reddish rhodochrosite and brown colored siderite in small crystals of the customary unit rhombohedral form were observed.

Ore-Minerals—

Pyrite.—The most abundant metallic mineral, far more abundant than all the others combined, is pyrite. This is not perhaps strictly an ore-mineral as, when pure, it carries no metals that can profitably be extracted. Still as will be shown in an assay to be given later, the pyrite of this vein, as is true of practically all pyrite in the mixed sulphide veins of the Cordilleran region of the West, does carry small amounts of gold and silver. This mineral occurs intimately intergrown with the massive quartz, irregularly distributed in the same, and rarely in pure masses. It is also very abundant in the irregular cavities or vugs that abound in this ore. In this case it forms small but well defined crystals. The customary habit of these crystals is that of the pentagonal dodecahedron, striated by the cube. Less commonly the cubic habit may be seen. In several cases additional forms were noted, namely, the octahedron, didodecahedron, and a second pentagonal dodecahedron. This mineral occurs in association with all the other sulphides named.

Sphalerite.—This is the second most abundant sulphide mineral in this ore. It seems to be more abundant in the higher levels than in the lower ones. At least, the dump of ore taken from the fourth and fifth levels does not appear to contain as much sphalerite as that from the levels above these two. The mineral is black or nearly black in color. It is to be distinguished from the other blackish sulphides by its good cleavage and brown streak. It occurs in granular masses in association with pyrite and galena. It was also noted in crystals of uncertain form in a vug together with pyrite, galena, chalcopyrite, tennantite, quartz, and rhodochrosite.

Galena.—This mineral is to be found in granular masses to a limited extent, but, as far as could be observed by examination of the ore dumps, it appears to be confined largely to the vugs or to the ore immediately adjacent to cavities. Where growing freely in a cavity it may have the form of the simple cube, but is more commonly in the form of the combined cube and octahedron. As is stated elsewhere it is more abundant in the upper workings of the mine. It does not carry much silver or gold values.

Chalcopyrite.—This mineral is usually intimately associated with pyrite in massive form and increases markedly in amount below the third level. It may readily be distinguished from the pyrite by its deeper yellow color. It very frequently occurs in small crystals in the vugs, in association with the other sulphides. The crystal forms are not usually recognizable, but in a few cases was determined as a plus and minus sphenoid.

Tennantite.—There are two minerals that commonly go under the name of gray copper. By far the more common of the two is tetrahedrite, a basic sulphantimonite of copper, 4 $Cu_2S.\ Sb_2S_3$. The other is the corresponding arsenic salt, $4Cu_2S.\ As_2S_3$, and is known as tennantite. Although tennantite is a comparatively uncommon form of gray copper, it is by no means rare in certain parts of Colorado, being known to occur in Clear Creek, Ouray, Rio Grande, and other counties of the state. The two minerals look so much alike that they cannot readily be distinguished without a chemical test. In the massive form which this usually takes in the Rawley vein it is very dark gray or blackish gray, shows no cleavage, and looks very much like chalcocite. It may be distinguished from that mineral by its extreme brittleness, and by the fact that, when very finely ground, it has a red streak of powder. Owing to the brittleness and softness of the mineral the streak may appear to be black when taken with an ordinary streak plate, as too much of the material rubs off on the streak plate to show the color. A scratch with a knife point will usually disclose a reddish streak

Tennantite appeared to be fairly abundant on the dump that came from the fifth and sixth levels. It occurs in solid masses several inches across. At least it was observed so occurring in several instances. But it usually occurs mixed with other sulphides in such a way as to make it impossible to identify it with certainty. Doubtless in the absence of enargite this mineral could be identified through the determination of arsenic with a blowpipe. As enargite has been identified in this ore this arsenic test would not be conclusive in the case of intimately mixed sulphides.

Tennantite was also observed to have crystal form, as would be expected, when it occurs in the cavities of the ore. The form is a simple tetrahedron, or the same slightly modified by a trigonal tristetrahedron.

Bornite.—On the dump derived from the fifth and sixth levels of the mine this mineral appeared to be fairly common mixed with chalcopyrite. It occurs in grains mingled with chalcopyrite and, to a less extent, with the other ore—and gangue-minerals. It has the customary pinchbeck brown color, but, owing to the extreme readiness with which this mineral tarnishes, its surface color is mostly a very dark blue, or a reddish blue, or greenish blue. In one case it was observed in minute crystals lining a small vug. The forms as far as could be recognized wer: octahedron and dodecahedron. They were observed in a vug together with tetrahedral crystals of tennantite.

Enargite.—This mineral is much less abundant than is chalcopyrite or tennantite in this ore, and is perhaps less abundant than bornite. It is difficlt to distinguish from the tennantite or chalcocite except when the cleavage is to be seen. This can always be depended upon where the grain is coarse or where individual crystals occur. In one case prismatic crystals were observed in a vug. In most cases, however, this mineral is to be seen in small granular aggregates intimately mingled with other ore-minerals in such a way as to make its identification difficult.

Chalcocite.—This apparently is the rarest of the copper minerals present in the Rawley ore. It was found very sparingly developed in one or two pieces of ore that came from the fifth and sixth levels. It may possibly be more abundant than appearances indicate, but, if so, it must be disseminated through the other sulphides in more or less invisible form.

Ore Values

As already stated there is a gradual change in the character of the ore from the first to the sixth level. On the upper levels galena is abundant, so that the ore is a silver-lead-copper ore. On the fifth and sixth levels copper and iron have increased and galena decreased very noticeably so that we there have a silver-copper ore. An interesting and rather unexpected change in silver values is to be noted in that, in spite of the decrease in the lead content with increasing depth, silver increases. To a slight extent this is also true of the gold. But gold plays so small a part in the total values that the increase in this metal does not add very materially to the gross value of the ore. So marked is the increase in silver values in the lower levels that, at a depth of 1,200 feet, the vein, where it is cut by the drainage tunnel, is reported to run twice as high in silver and gold values as in the upper levels.

Messrs. Simonds and Burns have kindly furnished a statement of the following

AVERAGE ANALYSES

Average ore from the four upper levels—

Lead-silver-copper ore.

Lead 10.15%

Copper	2.00	
Iron	9.00	
Zinc	4.00	
Sulphur	13.96	
Silica	60.45	
Lime, etc.	0.44	
Silver		9.03 oz. per ton

Average ore from fifth level—

Lead	4.76%	
Copper	4.43	
Silver		14.81 oz. per ton

Average ore from sixth level—

Lead	1.55%	
Copper	4.93	
Iron	23.66	
Zinc	1.00	
Sulphur	28.08	
Silica	37.00	
Undetermined	3.78	
Silver		13.25 oz. per ton

Average ore from twelfth level—

Lead	1.86%	
Copper	4.03	
Iron	34.00	
Zinc	2.11	
Sulphur	39.89	
Silica (Insol.)	13.50	
Undetermined	4.61	
Silver		24.00 oz. per ton
Gold		0.05 oz. per ton

Of course in case of the twelfth level the average analysis is made of a sample from very restricted ground, a single cross-section through the vein. The increase in silver over that of the higher level is certainly very marked.

From the above given facts it is evident that the silver values of this ore are not dependent on the lead. It was thought desirable, therefore, to determine to what extent the more important minerals of this ore carry silver and gold. With this object in view an assay for silver and gold was made by Messrs. Ho and Wang, two of the student members of the party, with the following result:

Mineral—	Gold.	Silver.	Total gold and silver values per ton (silver at 55c per oz.
Galena	0.02 oz. per ton	5.18 oz. per ton	$ 3.25
Pyrite	0.04 oz. per ton	7.16 oz. per ton	4.74
Chalcopyrite ..	0.05 oz. per ton	35.35 oz. per ton	19.34
Tennantite ...	0.08 oz. per ton	105.52 oz. per ton	59.64

From the above it appears that chalcopyrite and tennantite, especially the latter, carry most of silver and also most of the gold. Inasmuch as these two minerals appear to be relatively abundant on the ore dump from the fifth and sixth levels, the greater richness of the ore in silver and gold found in these two levels may be attributed to the greater abundance of these copper sulphides. To a certain extent the increase of gold and silver in the lower levels may be due to the pyrite which is said to be more abundant in the lower levels than in the upper ones, but, owing to its small content of these precious metals, the variation in the amount of pyrite probably effect the percentage of the precious metals.

The writer has not had access to the vein at the level of the drainage tunnel and is not informed as to whether tennantite is still more in evidence at that level than at the fifth and sixth levels, but the reported great increase in the silver content at the tunnel level would naturally lead one to expect a corresponding increase in the tennantite as well as of the chalcopyrite.

Assay values furnished by the company indicate an average ore value for the third, fourth, fifth and sixth levels of about $30 a ton, but the writer is not informed as to what extent this represents sorted ore. A sample taken by Messrs. Ho and Wang across the entire vein on the fourth level where it reaches its maximum width of sixteen feet gave the following assay values:

Gold.	Silver	Lead.	Zinc.
0.02 oz. per ton	7.08 oz. per ton	19.20%	3.48%

Figured in values with silver at 55 cents an ounce and lead at four cents a pound, and ignoring any possible values that may be derived from the zinc, this gives a gross value of $19.65 a ton.

Origin of the Rawley Vein

It is a very common thing to find veins of mixed sulphides carrying lead, copper, silver and zinc, like the Rawley vein, in which the lead in the form of galena occurs in greater amount in the upper workings than at a lower level. Such enrichment of the lead-bearing mineral near the surface is now generally supposed to have been brought about by the influence of downward working surface waters which, following the course of the vein, have dissolved the lead from near the surface and precipitated it in contact with the sulphides of iron and zinc at slightly lower levels. This pre-supposes the prior existence of a vein containing the mixed sulphides and that such a vein was originally deposited by waters rising from considerable depths. The deposition of the lead near the upper part of the vein by downward moving waters thus causes what is termed a secondary enrichment of the original sulphides. It is quite possible that the greater content of lead in the form of galena in the two or three upper levels may be accounted for such a secondary enrichment. But it is worthy of note in this connection that such secondary enrichment of lead-silver veins usually shows an enrichment of the silver content along with that of the lead. That this is not true in this case may, perhaps, be accounted for by the fact that silver is mostly confined to the copper minerals in this vein. There are other slight evidences of alteration of the vein by downward working waters that alone would have little or no weight. Among these may be mentioned the occasional occurrence of pseudomorphs of quartz after barite.

Against the theory of secondary enrichment may be mentioned the apparent absence of oxidation products, such as the carbonates of copper and of zinc, the almost complete absence of chalcocite, and the progressive increase in the silver values with the depth. As to the oxidation products, possibly such minerals may have been found in the surface workings in the early days, and have been worked out. But, if we are to explain the greater development of galena in the second, third and fourth levels by secondary enrichment it is difficult to believe that the copper sulphides would not have feen affected by the same waters that brought about the enrichment of the lead. Such enrichment of the copper would surely have resulted in the deposition of considerable chalcocite.

In order to ascertain, so far as possible, to what extent a secondary sulphide enrichment has taken place in this ore, three samples representing variations in the ore as disclosed on the dump coming from the fourth and fifth levels were submitted to

Mr. Augustus Locke of the Geophysical Laboratory of the Carnegie Institute for a microscopic study on polished specimens. As the result of this investigation he reports that:

Specimen No. 1 shows pyrite, galena, chalcopyrite, enargite, sphalerite and some threads of chalcocite cutting galena. The galena, chalcopyrite, enargite and sphalerite have the mutuality of relations which shows them to be contemporaneous. The pyrite may be of the same age, but we are not sure that it is not earlier. There is a very small amount of covellite developing from chalcopyrite. The chalcocite forms along the cleavage lines of the galena."

Specimen No. 2 "shows pyrite, chalcopyrite, enargite, bornite, tetrahedrite (tennantite) and chalcocite. Chalcocite is developing secondarily after bornite. The minerals other than the chalcocite are primary, the reasoning being the same as in specimen No. 1."

Specimen No. 3 'shows pyrite, galena, bornite and chalcopyrite. The galena, bornite and chalcopyrite are contemporaneous and primary."

It will be seen from the above that Mr. Locke finds that in one case the minerals galena, chalcopyrite, enargite, and sphalerite are of contemporaneous age; that in a second case the same holds true for pyrite, chalcopyrite, enargite, bornite, and tennantite; and in a third case for galena, bornite, and chalcopyrite. He finds that only chalcocite and covellite are assuredly secondary, and that possibly some of the pyrite may be secondary also. We must assume, therefore, that all the sulphides with the exception of the small amount of chalcocite and the mere trace of covellite are of primary origin. This appears to hold true for the galena as well as for the other sulphides and sulphosalts.

Whether all of these primary sulphides and sulphosalts are strictly contemporaneous in their growth may be doubted, but this could be determined only by the investigation of a larger number of specimens.

As secondary enrichment of these sulphide ores does not appear to have taken place to an appreciable extent, we may, perhaps, be justified in assuming that we have here a case of a zonal deposition of the sulphides by rising waters. Such rising waters, owing to variation in pressure and temperature at different portions of the water column, would deposit its mineral burden unequally in the lower and higher parts of its course. It would seem that the condition favorable for silver and copper deposition were found at the lower levels, and those favorable for the precipitation of lead nearer the surface.

If this theory is correct it argues for the continuance of the vein below the level of the deep drainage tunnel to a very considerable depth, unless, possibly, a change in the character of the adjacent rocks may cause a corresponding change in the character of the vein.

Veins Cut by the Drainage Tunnel

Undoubtedly in deciding to undertake the expense of driving a drainage tunnel of over a mile the mere draining of the Rawley mine was not the only object kept in view. The possibility or, rather, probability of cutting other veins was an additional incentive. Several veins were known to crop out on the surface along the proposed line of the tunnel, and several of them have been prospected to a greater or less extent. That the course of the tunnel was not made straight was due to the expectation that, by deviating slightly from a straight line, there would be a greater likelihood of striking at the tunnel level one or two veins that had been prospected on the surface. The dimensions of the tunnel were made such that it might serve as an operating tunnel, if desired, both for the Rawley vein and for other veins that might be cut by the tunnel.

The company did not care to give exact information as to the veins struck in the tunnel, especially with reference to those that might correspond with known surface veins. A number of small veins and ore streaks, also a large number of faults with varying strike and dip were encountered. The faults are accompanied with clay gouge and sometimes with marked brecciation of the country rock. Jasper may form one of the walls of a vein, but does not occur as a gangue.

At a point 2,800 feet from the portal of the tunnel a very strong vein was struck to which the name "Dr. Clark vein" has been given. It does not correspond with any known vein of the surface. No development of this vein has been made. At the time the tunnel was visited the vein was partly obscured by timbering so that exact measurements could not be made. It appears to be about 20 feet wide, strikes north-south, and dips 50° E. The ore is strikingly attractive. It consists of a coarse grained aggregate of sphalerite and galena with some pyrite and a very little chalcopyrite; also calcite, rhodochrosite and a little quartz. The gangue minerals form a comparatively small part of the ore. The scarcity of quartz is the more remarkable in that nearly all the ores of the Bonanza district are very siliceous. The gold and silver values are not known. The ore carries a very high percentage of sphalerite, which varies from dark gray to light yellow.

THE ANTORO MINE

Location and Development

The property of the Antoro mine, which is organized under the name of the Antoro Mines Company, is owned by David G. Weems and William B. Ellis, the manager and superintendent being John E. Ashley. The company controls thirteen claims that lie mostly north of the Rawley mine. The mine was originally opened through a shaft on the Antoro vein located near the top of the mountain at an elevation of about 11,650 feet (see map on Plate I, location D3). This shaft was sunk to a depth of about 150 feet and but very little development work was done through it. Nearly all development work has been done through or in connection with the driving of a tunnel that has very recently been completed. The tunnel portal is located at an elevation of about 11,100 feet, or approximately 550 feet lower than the collar of the shaft (see map on Plate I, location No. 11, at E3). The workings on the level of this tunnel make a total of about 7,200 feet. The original shaft located on the Antoro vein has been extended to the level of the main tunnel for the purpose of ventilation. About 150 feet from the portal a winze has been sunk on a vein that is supposed to be the Rawley vein. This winze is 225 feet deep. A map of the workings on the tunnel level is given on Plate XXI, in pocket A.

Geology

The geology of the mine is very simple. The rock is probably andesite alone. This cannot positively be stated on account of the extent to which alteration has progressed. Fault slips are numerous and are marked by clay gouge. Apparently the movement along the fault planes does not amount to more than a few feet. Four or five veins have been cut by the tunnel, but development has not progressed far enough to determine whether these are all independent veins. Three of these veins show much promise and are worthy of individual description.

Antoro Vein

This vein is cut by the tunnel at a point about 1,200 feet from the portal. The dip is 85° NE. The strike varies from N. 30° W.

to N. 40° W. This vein consists of a white, porous, mostly crystalline quartz with considerable white tabular barite, and galena. The galena is argentiferous, the values being lead and silver with some gold and copper. In driving the tunnel a small carload of shipping ore was taken out. In the Antoro shaft, which is not vertical but follows the vein, for about 200 feet from the tunnel level upwards, the vein is well developed, averages about two feet in width and carries ore rich enough to ship.

East-West Vein

This vein is cut by the tunnel about 1,000 feet from the portal. Although it goes under the name of the east-west vein, the strike is very fluctuating and does not follow very closely an east-west course. Where observations were made on this vein it was found to strike N. 30° W., and to dip 30° NE. The vein has been drifted on for a distance of some 600 feet and more or less stoping had been done by August, 1914, for a distance of about 250 feet.

In the stope at the date above mentioned a good body of ore was disclosed that showed from three to five feet of shipping ore, below which milling ore occurred to a thickness not determined. This ore runs

Lead	35%
Silver	8 to 12 oz.
Zinc	less than 4%

The gangue of this ore is quartz which may contain vugs in which crystals of galena ¼ to ½ inch in diameter are to be seen.

The form of these crystals is that of the cube and octahedron in about equal development.

The character of the ore in this east-west vein of the Antoro mine, as well as the values of the same, may be seen from the data given below, which are taken from the official returns of the Ohio and Colorado Smelting and Refining Company at Salida, to which place the ore was shipped. In these returns the cost of haulage is not taken into account. It is as follows:

Cost of haulage per ton of ore:

Wagon to Villa Grove	$4.00
Railroad to Salida	1.75
Total	$5.75

The column given below and headed "net value per ton" means the net value after paying smelter charges, but not including haulage.

Smelter returns on East-West vein ore:

Date	Net lbs.	Ounces Au.	Ounces Ag.	Per Cent Pb.	Net Val. per ton
Oct. 14, 1913	37.332	.025	11.75	40.4	29.39
Dec. 16, 1913	47.724	.015	7.9	29.7	14.22
June 3, 1914	52.172	.025	9.0	37.95	19.25
June 23, 1914	53.756	.025	8.4	31.9	15.33
June 29, 1914	52.034	.022	7.35	30.8	14.32
June 29, 1914	52.160	.105	11.2	23.1	13.68
July 15, 1914	51.322	.02	7.75	31.3	14.68
Aug. 4, 1914	45.382	.015	8.0	29.2	13.19
Aug. 13, 1914	42.228	.02	7.95	29.05	12.83

Rawley Vein

At a point about 150 feet from the portal of the tunnel a vein is exposed in a winze which has been sunk to a depth of 125 feet. This winze was filled with water at the time the mine was examined and could, therefore, not be entered. In the opinion of Manager Ashley this vein is the continuation of the Rawley vein of the Rawley mine. He states that the ore is exactly the same as the ore of the Rawley vein, and that its position, strike and dip conform therewith. Some pieces of this ore exposed on the dump were examined by the writer and were observed to bear a close resemblance to the Rawley ore. They consisted of pyrite and chalcopyrote in a hard dense quartz-gangue. A study of the map contained on plate 21, which gives a plan of the Rawley and Antoro workings, would seem to indicate that this assumption is reasonable.

Mr. Ashley is of the opinion that he has also struck the Rawley vein at another point 700 feet from the portal. The vein at this point is "tight," one to two feet wide, and carries mostly zinc and a little lead and silver, but no copper or gold. It shows a strike of N. 5° W., and dip of 75° E.

In the above description of the veins of the Antoro mine the writer has in most cases taken the statements of Manager Ashley as to values and dimensions, as he was not in position to verify them by personal investigation. The development done in the mine is not sufficient to indicate the extent of the ore bodies that may be present.

THE CORA MINE

The Cora mine (position No. 28, Plate I, in pocket, location E3) is located about 1,000 feet west of the Antoro tunnel at an elevation between 11,000 and 11,100 feet. It was worked many years ago through an inclined shaft which, at the time this survey was undertaken, was inaccessible because of bad air. The ore, as indicated by material now exposed on the mine dump, is composed essentially of galena, sphalerite, pyrite, and quartz. The mine is said to have produced about 200 tons of $35.00 ore, or a total value of $7,000.00.

MICHIGAN AND GEM CITY MINES

These two properties are situated on the mountain slope on the north side of Rawley creek, about 700 feet apart, and an equal distance from the creek, at an elevation between 11,200 and 11,300 feet (position No. 26 and 27, Plate I, in pocket, location E4). Both of them are located on the Michigan vein. They are hardly more than prospects. The Michigan was worked many years ago, at which time there was taken out about 700 tons of $35 ore. Two drifts have been worked, but are in bad condition at present.

At the Gem City a cross-cut was driven in 1912 for the purpose of opening up the vein. The Michigan vein is best seen in this Gem City cross-cut. The strike and dip are the same in the cross-cut as in the discovery shaft of the Michigan mine. The vein strikes N. 20° E. and has a dip of 58° E. It is a strong vein, showing a width of five feet in the Michigan shaft, and can be traced in a northeasterly direction over the mountain, for a distance of about half a mile, to the Emma shaft. This shaft is situated on the east slope of the mountain several hundred feet below the summit and beyond the range of the map accompanying this report.

The ore minerals are galena, sphalerite, gray copper, and pyrite. The gangue is quartz and barite, the quartz being more or less porous and crystalline.

The Michigan vein is one of the best defined and most promising of the undeveloped veins of the district, but it has not been opened up sufficiently to disclose its real worth.

MINES ON THE PARAGON VEIN

In the description of the Rawley mine attention was called to a strong line or, rather, zone of faulting that appears in the mine workings and also in the drainage tunnel. This fault is locally mineralized to some extent, carrying streaks of white quartz, which may be accompanied with sulphides. It is usually referred to locally as the Paragon vein. This vein follows approximately the course of the upper Rawley gulch above the Rawley mine. It strikes a little north of east and dips 55° to 60° S. and has been traced for a mile and a half or more.

A number of mines and prospects have been opened up along this vein in Rawley gulch above the Rawley mine. Three of these are located on the map of Plate I. These are the Paragon (position No. 19), the Great Mugul or First Chance (position No. 34) and the Rainbow (position No. 33).

The Paragon Mine

The Paragon vein was named from the first mine opened on this vein. This is located just east of the Rawley mine. Information is not available as to the amount of work done on this property. So far as known, no ore was ever shipped from it, and probably none was ever discovered rich enough to ship.

The Great Mogul or First Chance Mine

These two names appear to be used interchangeably for a property located on the Paragon vein nearly half a mile above the Rawley mine, on the south side of the gulch. The mine tunnel could not be entered, as it was choked with ice. Owing to its position it is assumed that it is located on the Paragon vein. The tunnel dump carries galena, pyrite, sphalerite, and quartz, also a little barite and quartz, pseudomorphous after barite.

In the list of mines that shipped ore previous to the year 1900, and found on page 68, the Great Mogul and the Last Chance are listed separately. Both together are supposed to have shipped 140 tons of $40 ore.

The Rainbow Mine

This is merely a prospect. It is owned by the Hazard Mining Company, and is located at the upper end of Rawley Gulch. A little ore has been found, but none rich enough to ship. A tunnel 650 feet long has been driven, of which distance 450 feet is along the vein. The rock is an andesite breccia. The vein shows parallel stringers of quartz, strikes N. 85° E., and dips 60° S.

THE WHALE MINE

The Whale mine is located on the north-sloping mountain side about 1,200 feet south of the Rawley mine (Plate I, in pocket, location 20). It worked a north- and south-striking vein through several shafts and tunnels that were inaccessible at the time examination was made. It was worked regularly from 1882 to 1890, after which for several years it was leased. That at one time the mine was a property of some consequence may be seen by the fact that, up to the year 1893, the mine shipped ore to the value of $100,000.00. This was a silver-gold-copper ore averaging $50 to the ton.

Most of the valuable ore was shipped from the upper workings, in which the ore carried mainly lead and silver values. In the lower workings the ore was a copper-silver proposition, the copper coming in the form of chalcopyrite. In this respect the ore resembles that of the Rawley vein in that it changes from a lead-silver to a copper-silver body in passing from the higher to the lower workings.

THE SUPERIOR-ERIE MINE

These two mines are worked through a common shaft which lies on Superior ground, although most of the ore has been taken out of the Erie mine. The shaft is located near the top of the ridge immediately south of the Rawley mine, and at an elevation of nearly 11,000 feet (Plate I, in pocket, location 21, F3). The shaft is inclined, following the vein except for the upper 25 feet, where it is vertical. Development work has been done on four levels. The Superior is owned by the D. J. McIntosh heirs and the Erie by L. W. Sharpe, to whom the writer is indebted for the information that appears in the following paragraph.

The Superior-Erie vein averages 18 inches to two feet in width, with a maximum of five feet. It strikes N. 68° E., and dips 35° E. The ore runs on an average $40 to the ton and assays

Lead	20%
Zinc	5%
Copper	3%
Silver	30 ounces
Gold	.1 ounce.

The Erie has been a paying proposition. The mine has paid on the average an amount that would be the equivalent of 10 per cent on an investment of $30,000 for the years 1893 to 1914. The Superior claim is not patented.

The mine was working in a small way in 1912, a small steam hoist being sufficient to hoist the ore, which is loaded into buckets. No pumping is required, as the mine is dry.

The ore consists of pyrite, galena, sphalerite, and chalcopyrite, with a gangue of quartz and a little rhodochrosite.

THE HANOVER MINE

Immediately west of the Whale mine is the Hanover mine (Plate I, location No. 25, F3), owned by Messrs. Buck and Sharp. This property is worked through a tunnel and inclined shaft. The vein is very similar to those in the immediate vicinity. It strikes S. 60° E., and dips 15° N. The ore consists of galena, sphalerite, chalcopyrite, and tatrahedrite, in a gangue of quartz and barite. It is essentially a lead-silver property. It produced previous to 1900 700 tons of ore valued at $17,500.00, averaging $25 to the ton.

THE MINNIE LYNCH MINE

This property is located on the north slope and near the crest of the ridge between Rawley and Copper gulches (Plate I, location 30, G3), and is owned by Mrs. Ollie Murphy. The vein carries galena and sphalerite and is similar to the other veins of the vicinity. It is from three to five feet wide, strikes N. 85° W., dips N. 73°, and is worked through an extremely crooked tunnel. But very little work has been done on the vein. About 60 tons of $40.00 ore had been taken out previous to 1900. In the spring of 1914 some very good ore seems to have been struck, at least four tons having been shipped that brought $79.00 to the ton. The ore is said to have been a greenish colored silver chloride. On the strength of this new discovery a new road was constructed in 1914 from the Rawley gulch road up to the mine.

THE BLACK BESS MINE

This property on which only assessment work has been done is owned by M. E. Wilder and W. S. Wilder. It is located at the summit of the ridge between Rawley and Squirrel gulches (Plate I, location 17, F3). The vein is two feet wide, strikes N. 15° E., and dips 35° E. It was worked through an inclined shaft dipping 42° for the first 100 feet, then 20° for 50 feet, then 40° for another fifty feet. The ore as far as developed is essentially a zinc ore. A few cars have been shipped that ran 33% zinc, 10% lead and 3 oz. silver.

MINES NORTH OF RAWLEY GULCH

THE SHAWMUT MINE

The Shawmut mine is located near the summit of Round Mountain on its south and southwest slope (Plate I, locations 3 and 4, C3) and includes the Shawmut and the May Belle vein. The property is owned by the Kapi Mining and Milling Company. It includes four claims, namely, Shawmut, May Belle, May Belle I, and May Belle II.

The two veins are similar in character and have nearly parallel strike, but differ considerably in dip. The Shawmut vein lies to the east of the May Belle vein and outcrops on the level of the extensive flat to the south of the summit of Round Mountain. The rock at the surface is Bonanza latite. Probably the vein passes downward into andesite, but this has not been demonstrated. The May Belle vein outcrops lower down the slope towards the west and lies in andesite.

The Shawmut Vein

As shown on the first level of the Shawmut mine, this vein is about two feet wide, strikes N. 15° E., and dips vertical. The ore consists of pyrite, gray copper (probably tennantite), chalcopyrite, and galena, with a quartz gangue. The vein has produced about 700 tons of $60 ore, yielding a total gross value of $42,000.00.

It is worked through a vertical shaft 300 feet deep. The vein has been drifted on in five levels with very little stoping. The lengths of these drifts, from the first to the fifth, respectively, are 150, 250, 560, 460, and600 feet, making a total of 2,020 feet.

When the mine was visited in 1912 it was filled with water up to the second level and was accessible only on the first level. As stated above, the rock at the surface is Bonanza latite. Owing to the position of this latite which appears to overlie the andesite on Round Mountain, and to the fact that the May Belle vein and tunnel are in andesite, it is more than likely that the lower workings of the Shawmut vein are in andesite. The water in these workings made it impossible to determine this matter. It is possible that the line of contact between the overlying latite and the underlying andesite dips so steeply to the east as to bring it below the Shawmut shaft, but this is not considered as at all likely. A vertical section through the workings of the Shawmut vein parallel to the strike is shown on Plate I (in pocket).

A sample of ore was taken on the first level by channeling across the vein at the breast. It gave the following:

	Assay
Silver	40.2 oz.
Gold	.2 oz.

The May Belle Vein

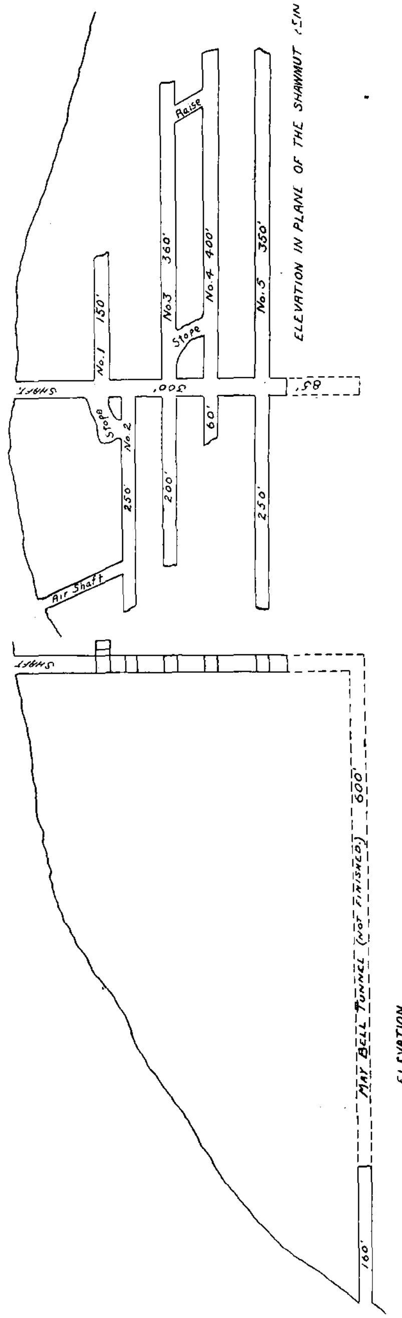
This vein was formerly known as the Wide Awake. It is similar in character to the Shawmut vein, being composed of galena, gray copper (probably tennantite) chalcopyrite, pyrite, with a gangue of quartz with which occurs also barite. To a slight extent the copper ore has been altered to malachite. The country rock is andesite. The vein strikes N. 25° E., and dips 66° E. It lies about 300 feet west of the Shawmut vein.

This vein has been worked through a tunnel, the so-called May Belle tunnel, which cuts not only the May Belle vein, but one or two other veins lying west of this. This vein was not inspected by the writer. It is said to be about 11 feet wide and to contain several ore streaks of varying width. Previous to 1900 it is supposed to have produced 30 tons of $50 ore.

In the summer of 1912 a tunnel was started about 80 feet lower than the May Belle tunnel, with a view to cutting both the May Belle and the Shawmut veins. This tunnel is at a level 165 feet below the bottom of the Shawmut mine, so that, when it reaches the Shawmut vein, it will not only unwater the lower workings, but will permit the driving of two other levels above the water level. By the summer of 1914 this tunnel had been driven 248 feet. The total distance from the portal to the Shawmut vein is 923 feet.

THE VIENNA MINE

A small property on the western slope of Round Mountain, at the same elevation as, and about 1,500 feet northwest of the Shawmut mine, is known as the Vienna Mine. It is owned by



WORKINGS OF SHAWMUT MINE.

FIG. 2.

C. H. Eaton, an old prospector, who has been working at this property on and off for many years. The vein is worked through a tunnel which follows for the most part the course of the vein, and is 65 feet long. At the breast the vein strikes S. 5° E., and dips 24° E. The ore is galena and gray copper. A sample of this ore from the breast was assayed and gave 66.2 ounces in silver.

A cross-cut has been started about 50 feet lower.

THE SOSTHENES MINE

This property, owned by John B. Baldwin, has evidently seen considerable development, judging from the four tunnels and the very considerable surface equipment. It is located a short distance north of the Alder road that climbs Round Mountain (Plate I, in pocket, location 28, E3). The surface plant embraces

1 Air compressor, 8 by 14 in.—9 by 8 in.
1 Horizontal fire-tune boiler, Hendrie and Bolthoff
1 Pump, Platt Iron Works
1 B. F. Sturtevant air pump for ventilation
1 Blacksmith shop with accessories
Engine and tunnel house.

Of the four tunnels only two could be entered because of cave-in, and these for only about 150 feet. In neither case was the vein accessible. For the following information concerning this property the writer is indebted to Mr. J. P. Poole of Bonanza.

The Sosthenes mine was worked from about 1887 to 1893 and produced 400 tons of $100 ore. The upper levels were oxidyzed and produced silver and gold. The ore of the lower levels consisted of sulphides of lead and zinc. The shipping ore showed the following:

Sosthenes Ore Values

12 to 15%	zinc
15%	lead
.04 oz.	gold
35 oz.	silver

OTHER MINES

There are a number of other mines within the region north of Rawley gulch that have more or less ore, but concerning which no very definite information could be obtained. Among these may be mentioned

Legal Tender	(Plate I, location 29, C4), production	$ 4,000.00
Payson	(Plate I, location 38, D3), production	30,000.00
Little Jenny	(Plate I, location 37, D3), production	12,500.00

MINES ON KERBER CREEK

THE BONANZA MINE

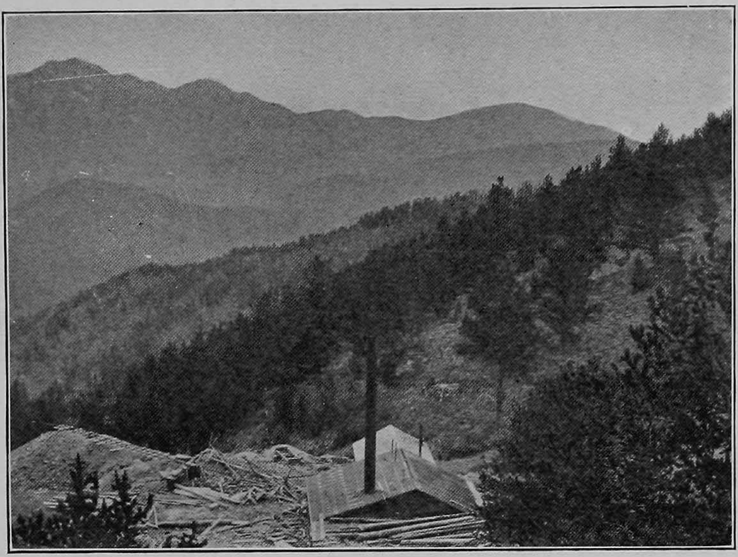
History and Development

The Bonanza mine was one of the first to be opened in the Bonanza district and was one of those that was responsible for the sudden growth of Bonanza camp. This was due to the discovery at the surface of a very considerable ore body that is said to have run two hundred dollars to the ton. The estimated output of this mine up to the year 1900 is $300,000. Since that date the mine has been operated part of the time, but figures giving the values produced are not available.

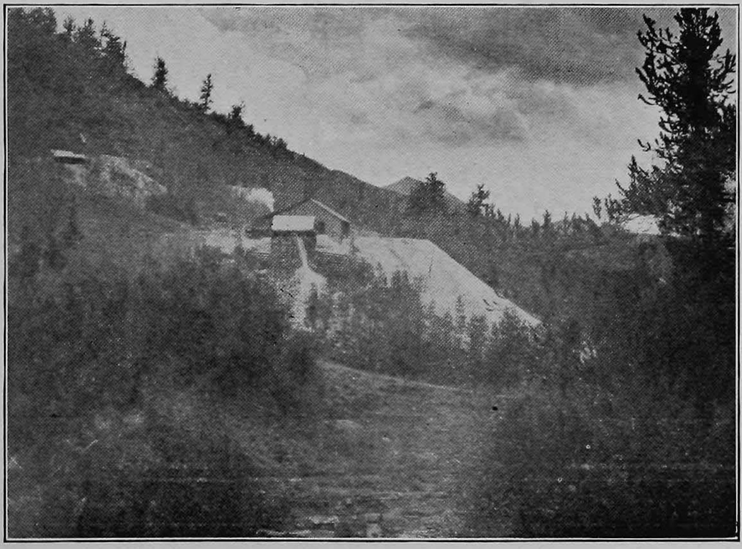
The property embraces the Bonanza, Bonanza No. 1, and Cornucopia claims, and is owned by the heirs of Edwin C. Barr of Springfield, Mass. It was leased to Dennison Cowles of Brattleboro, Vt., and subleased to the Saguache Mining Company. The mine and mill were operated by the above named company with W. P. Cary as manager during the year 1912, during which management only milling ore was worked. These operations ceased in 1913 and the property was further subleased by the Saguache Mining Company to Dan Mahoney of Bonanza. Under Mr. Mahoney's lease several men were at work taking out shipping ore in August, 1914, at the time the mine was visited the last time.

The mine is worked through an inclined shaft located on the Bonanza claim. This is located on the east side of Kerber Creek about a mile and a half above the town of Bonanza (Plate I, location 1, F2). The mine has been developed to a depth of 400 feet, there being six levels, on each of which considerable drifting has been done, as shown below.

	Depth of level below surface	Amount of drifting
1st level	105 feet	250 feet
2nd level	150 feet	200 feet
3rd level	200 feet	350 feet
4th level	300 feet	900 feet
5th level	350 feet	400 feet
6th level	400 feet	300 feet



A. Sosthenes mine, with Mount Antoro in the distance.



B. Bonanza mine, in Bonanza Gulch.

Above the third level the main part of the vein is stoped out. On the fourth level at the shaft is a stope 80 feet long by 40 feet high by 10 feet wide. There is also a raise through level 3 with a stope 150 feet long by 35 feet high by 8 feet wide. On the fifth level is a stope 60 feet long by 20 feet high by 2½ feet wide, also another stope 12 feet wide by 45 feet high by 35 feet high. No stoping has been done on the sixth level.

In August, 1912, the mine was employing nineteen men including bosses, and was working in two eight-hour shifts. Ore had been blocked out mostly on the 4th level that was supposed to measure 29,000 tons. The hoist has a capacity of 160 700-pound buckets of ore in 24 hours. Water was hoisted between shifts at the rate of eight gallons a minute. Two hours a day sufficed to hoist all the water. The costs involved in mining this ore may be seen from the following table of

Costs

Mining and hoisting	$2.50 a ton
Haulage to mill	.70 a ton
Wages for muckers	3.00 a shift
Wages for machine man	4.00 a shift
Wages for engineer	4.00 a shift
Wages for shifter	4.00 a shift
Coal, delivered at mine	9.35 a ton
Cordwood, del'vd at mine	$1.75 to 2.00 a cord

The Bonanza Vein

The bonanza vein lies in Bonanza Latite. The strike is approximately east and west, but may vary about 20°. The dip also varies considerably, but averages about 48° N. The ore consists of galena, pyrite, sphalerite, chalcopyrite, also sometimes gray copper, in a gangue essentially of quartz and a small amount of barite (the ore averages 4% BaO). Fluorite has also been observed. The quartz is mostly fine grained, but not cherty in texture, and not usually crystalline. It is a replacement product of the latite. The vein in its fullest extent is not a fissure vein, but appears to occupy a line or narrow zone of rock brecciation. The walls may in places show a fault slip, but usually are ill defined. Parallel veining of the quartz is not ordinarily to be seen. In places, however, within the walls of the vein there may occur a sharply defined mineral vein or streak with white massive quartz, containing quartz-lined vugs and much galena. Such a galena streak was observed in the midst of the main vein on the first level which had been opened by lessers in the summer of 1914. This streak was between two and three feet wide, had solid walls without any clay gouge, and consisted of galena to the extent of 30 to 50% of the bulk of the ore. This ore streak formed only a part of the main vein, which at that point was perhaps ten or twelve feet wide. This galena-bearing portion of the vein has the appearance of a fissure vein. It may very possibly represent the filling of a fissure that was opened in the main vein at a date later than that at which the main body of the ore was formed. The Bonanza vein pinches and swells, varying from two feet to fifteen feet in width. It averages about four and a half feet in width.

The values found in the mill dirt in 1912 were as follows:

Lead	9%
Zinc	17%
Copper	.5%
Silver	4½ oz.
Gold	.01 oz.

The vein is said to be much richer in lead on the 100 foot level than it is at lower depths. Below this level zinc in the form of sphalerite increases and is very abundant between the 200 and 300 foot levels. It was noticed that the sphalerite streaks on the 300 foot level were accompanied by a clay gouge on the hanging wall. Such streaks were one-half foot to two feet wide and the clay gouge a foot or more wide.

Copper which appears to be missing in the upper levels appears in the 300 and 400 foot levels. This copper is said to occur mainly as gray copper.

Oxidation products are not very abundant in this vein. Occasional streaks of iron oxide indicate partial oxydation. An oxydation zone occurs on the 3½ and 4th levels that marks a former water course. Some lead and zinc carbonate has been found in this place. It is interesting to note that this level of the mine is much below the level of Kerber creek.

Evidences in this mine seem to point more strongly than in most other mines of this district to a secondary concentration of sulphides in the upper levels. This is seen in the rich veins or streaks of galena at the 100 foot level, in the increase of zinc sulphide below this level, and in the great decrease of the lead values at the lowest levels. The occurrence of copper at the lower levels is also worthy of special note, as it accords with what seems to be the rule of the camp. This secondary enrichment of the lead-silver values in the upper levels is generally held to have been brought about by means of descending waters.

The Bonanza Mill

This mill is a custom mill, owned by the Bonanza Milling Company. It has been used, however, only for the treatment of ore from the Bonanza mine, so that its description may well be made in connection with that of the Bonanza ore body. At the time the field work of this report was done the mill as well as the mine were under the management of W. P. Cary. Most of the information concerning this mill was given by Mr. Cary and gathered by Rastus S. Ransom, Jr., and C. J. Daman, student-members of the party.

The mill is located on the west side of Kerber Creek a short distance below Bonanza, and about two miles from the Bonanza mine. The power is furnished by an 80 h. p. Babcock and Wilcox boiler driving one 40 h. p. Fairbanks-Morse upright engine, and one 20 h. p. Fairbanks-Morse horizontal engine. The cost of milling the Bonanza ore is $1.49 a ton. The capacity of the mill is 50 tons per 24 hours, the mill being run in three eight-hour shifts. The following are some of the cost items.

Coal, delivered at the mill........	$8.35	a ton
Wood, delivered at the mill.......		a cord
Shifter's wages	4.00	
Crusherman's wages	3.00	
Firemen's wages	3.50	
Laborer's wages	3.00	

The fuel consumed daily is twelve hundred pounds of coal and three cords of wood. The ore is concentrated into a lead concentrate and a zinc concentrate; the lead being shipped to the Ohio and Colorado Smelting and Refining Company at Salida, Colo., and the zinc to the United States Zinc Company at Blende.

ORE REFINING CONTRACTS

ZINC—

The contract under which the zinc concentrate was sold in 1912 is as follows:

The zinc concentrate is sold for $19 a ton provided the concentrate runs

Zinc	35%
Lead	10%
Gold	.04 oz.
Silver	8 oz.

If gold assays more than or less than .04 oz. an amount is added or deducted based on the rate of $19 an ounce. Similarly, if silver values differ from the agreed 8 oz. a ton an amount is added or subtracted based on the rate of $0.45 an ounce.

For every unit of zinc above or below 35% add or subtract $1.00.

For every unit of lead above or below 10%, dry assay, add or subtract $0.30.

For every variation of $0.05 from the St. Louis quotation on spelter above or below $6.00 there is added or subtracted from the base price $0.25.

Three quarters of 1% CaO is allowed free. The contract calls for 300 tons a month.

LEAD—

The contract under which lead concentrate was sold is as follows:

The lead is figured on 90% of content minus one and one-half units, minus one and one-half cents per pound based on New York quotations on day of assay. No treatment charges if the lead is over 40%, wet assay. For every unit above or below 40% there is added or deducted $0.10.

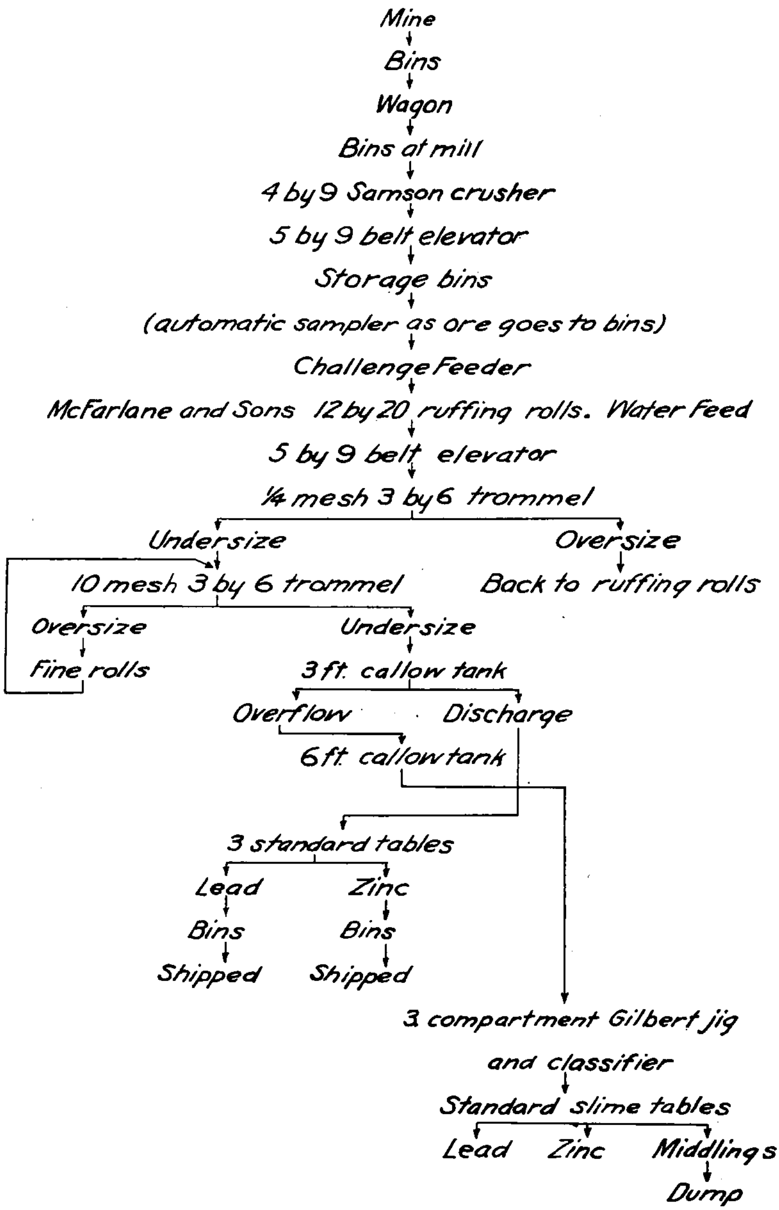
Copper is paid for on basis of minus one and one-half units of content at New York quotations on day of assay.

Iron is paid for on basis of $0.10 for every unit in excess of silica.

Silica is charged for on basis of $0.10 for every unit in excess of iron.

The manner of treatment of ore at the Bonanza mill is indicated in the following:

FLOW SHEET


Mine
Bins
Wagon
Bins at mill
4 by 9 Samson crusher
5 by 9 belt elevator
Storage bins
(automatic sampler as ore goes to bins)
Challenge Feeder
McFarlane and Sons 12 by 20 ruffing rolls. Water Feed
5 by 9 belt elevator
¼ mesh 3 by 6 trommel
Undersize
Oversize
10 mesh 3 by 6 trommel
Back to ruffing rolls
Oversize
Fine rolls
Undersize
3 ft. callow tank
Overflow
Discharge
6 ft. callow tank
3 standard tables
Lead
Zinc
Bins
Bins
Shipped
Shipped
3 compartment Gilbert jig
and classifier
Standard slime tables
Lead
Zinc
Middlings
Dump

THE MEMPHIS MINE

This mine was formerly known as the Arkansas mine and is located about 1,000 feet south of the Bonanza mine on the west side of Kerber Creek. It is owned by Mr. G. Whiteman of Villa Grove, Colo. The country rock is the Bonanza latite and shows a marked structure. The flow-planes show a strike of N. 20° W., and a dip of 31° W.

The mine was worked through a shaft 100 feet deep. There are two levels, one at 20 feet from which most of the ore has come, and inaccessible at the time the mine was visited, and one at 100 feet depth. In the second level is a vein with east and west strike and dip 80° N. The ore is mostly galena and sphalerite in a quartz gangue. The vein appears to be a replacement of the country rock along a line of brecciation. The mine is said to have produced ore to the value of $5,000, but the values are very irregularly distributed.

THE EXCHEQUER MINE

Directly opposite the Memphis mine, on the east side of Kerber Creek, is the Exchequer mine. This mine has been a very respectable producer, as there have been shipped 500 tons of $125 ore, making a total output of $62,000.00. It has been worked through a tunnel the portal of which is at the level of the Kerber Creek road. At about 350 feet from the portal the main cross-cut tunnel is caved in, so that it is impossible to see what is beyond. Two faults containing more or less mineral are cut by this tunnel between the portal and the cave-in. The first appears to be only slightly mineralized and to consist mainly of a quartz gangue with a little rhodochrosite. It strikes N. 70° W., and dips 32° NE. This fault vein is 140 feet from the portal. The second fault is cut by the tunnel 250 feet from the portal. It strikes N. 30° W., and dips 22° E. It is marked by a heavy clay gouge. This fault has been drifted on for some distance, but water and ice prevented an examination.

OTHER MINES

Considerable work has been done at various places along Kerber Creek above the town of Bonanza in the line of prospecting and developing, and in some cases the values produced have been enough to encourage long continued efforts to open up profitable mines. Most of these properties are in very bad shape, and cannot be examined, while others have been abandoned for lack of encouragement. A brief mention of two of these properties will suffice for present purposes.

The Cocomonga Mine

This property is controlled by the owners of the Bonanza mine. It is situated on the opposite side of the creek from the Bonanza mine (Plate I, location 15, F2). It was worked by a shaft 150 feet deep. The shaft is very wet and the ladder in such shape that it is not safe to go down it. It is reported that some very rich ore has been taken from this property, but information is not available as to the values produced. An effort was made to connect this mine with the Bonanza by a drift or cross-cut, but for some reason unknown the attempt was abandoned.

The Saint Joseph Mine

This property is owned by Mr. C. Widmayer. It is situated about half a mile above the town of Bonanza on the east side of the creek (Plate I, location 23, H2). A great deal of work has been done in an effort to develop this mine into a paying proposition. It is said to have produced ore to the value of $15,000. The ore carries lead, zinc, and silver, and, in certain parts of the vein, has run as high as 1 oz. in gold. Owing to this gold content and to its position Mr. Widmayer has considered that this is the extension of the Josephine vein. The vein has been worked through two tunnels, the lower of which is over 560 feet long. Owing to the condition of the ground it was difficult to make out strike and dip of the vein. Mr. Widmayer has indicated the approximate course of the vein on the surface as N. 74° W.

MINES IN COPPER GULCH

THE EMPRESS JOSEPHINE MINE

History and Development

The Empress Josephine mine has been one of the greatest producers in the Bonanza district. Its total output up to the year 1900 is reported as the same as that of the Bonanza mine, namely, $300,000. Probably there has been comparatively little produced since that date. The ore has averaged about 60 dollars to the ton. Like other mines in Copper Gulch this mine produces ore relatively rich in gold and copper in dictinction from the more northerly located mines in which silver-lead ores are more abundant and gold is scarce.

The mine is located in Copper Gulch about a third of a mile northeast of the town (Plate I, in pocket, location 13, H3). It is owned by S. G. Everett of Cleveland, Ohio. Two claims were originally taken up, the Empress Josephine and the Boss Mammoth, joining each other end for end, and a shaft was sunk on the vein at the line where the two claims join. Subsequently this property. This shaft is not quite vertical, but conforms to the average dip of the vein, which is between 83° and 85°. The shaft is about 500 feet deep and is filled with water up to the fourth level. The mine is now under lease to Frank Leavitt of Villa Grove, Colo. The four levels that are above water are not entirely accessible on account of the caving in of the roof.

The first level has been apparently worked out and abandoned. Stopes from the second level have been broken through the floor of this level. On account of caved ground only about 100 feet could be studied.

The second level is developed east of the shaft only. It has not been completely worked out. A winze connects with the third level at about 270 feet from the shaft. At 350 feet the drift is blocked by a cave-in. At this point acid water enters the drift and attacks steel so vigorously as to require the laying of wooden rails. No timbering is required of the first two levels.

On the third level, which is developed on both sides of the shaft, some timbering is required. Stoping on this and on the fourth level has not been developed very systematically. Much of the work of late years has been done by leasers who have been interested only in getting out as much and as rich ore as possible with the least possible labor. They have been content with following the ore without regard to future development.

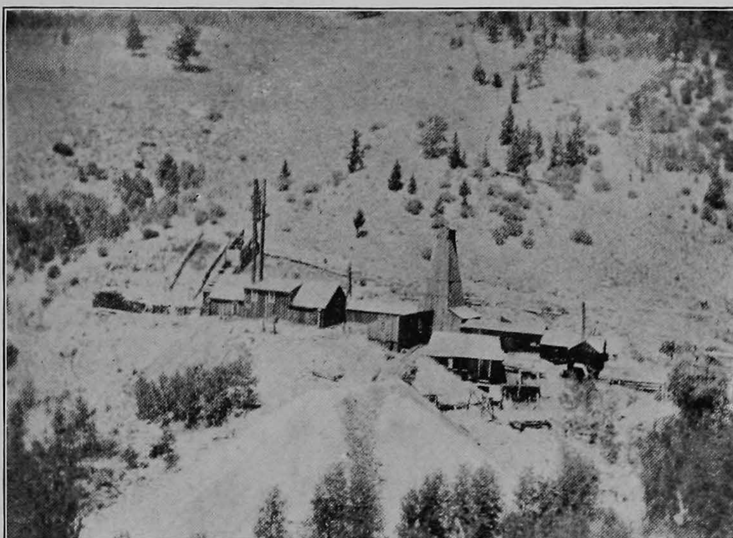
Equipment

The equipment is fairly complete for ordinary purposes, although some of it is not in the best condition. It includes

1 Hoist (Lightning hoist) by Hendrie and Bolthoff, intended for hoisting one-ton buckets

3 Boilers by Hendrie and Bolthoff, supplying steam for hoist and pumps

1 Small pump (make unknown) for emergency purposes



The Empress Josephine Mine

1 Wooden feed-water tank

Several pumps, not all in use, by Snow Steel Pump Works, Buffalo, N. Y.; by Dean Pump Works, Holyoke, Mass.; Cameron Vertical Steam Pump.

Assay office partially equipped.

Shaft house, Ore sorting house, Ore bins, Powder house.

The Josephine Vein

The mine is worked almost entirely on one vein. This is a fissure vein with usually well defined walls. It varies from one foot to two or three feet in width. The strike fluctuates considerably, but averages about N. 75° to 80° E. The dip is also irregular. The vein is mostly very steep with a northerly dip that averages at the shaft 83° to 85° N. It lies in Bonanza latite. The vein is cut by several faults which are usually marked by strong clay gouge. Only one of these faults displaces the vein more than a few feet. This is located several hundred feet east of the shaft on the third level. The fault plane has a strike of N. 10° W. and a dip of 50° E. It cuts the vein off sharply. Between the shaft and this fault the drift on the third level follows the vein, but beyond the fault no trace of the vein has been found. The drift was continued in the same general direction and, at 450 feet east of the fault, strikes the Hortense vein, which is a vein of the same general character as the Josephine vein, with about the same strike and dip, and is known to lie to the south of the Josephine vein. From this it would appear that the above mentioned fault must throw the Josephine to the left, that is, to the north on the east side of the fault.

On account of caved ground this fault was not accessible in the summer of 1912 at the time the mine was first studied. In the summer of 1914 the obstruction had been removed and the fault was easily reached.

As above stated, the ore values in the Josephine vein are very unevenly distributed. The ore occurs in shoots that are about 25 to 30 feet in breadth (in one case 100 feet) and that run from at or near the surface down to the 400 foot level and probably further. These ore shoots have a pitch to the east in conformity with a series of faults that also pitch to the east. The shoots are often bounded on one or both sides by these faults.

Below the 80-foot level the vein consists of unoxydized sulphides. The ore of the upper oxydized 80 feet is said to have contained lead, silver and gold, but no copper. The lead was in the form of the carbonate cerussite.

It is probable that the rich values in silver found in the upper levels were due largely to secondary enrichment by descending waters. Certainly the oxydized ores near the surface are to be accounted for in this way. But it was difficult to get very satisfactory evidence on this point from direct examination of the mine, as very little ore was at the time of examination accessible.

Ore-Minerals

The Empress Josephine vein has a rather rich assortment of minerals. So far as could be ascertained the following listed minerals have been found in this vein:

Quartz	Native Copper
Pyrite	Native tellurium
Galena	Richardite
Chalcopyrite	Sylvanite
Sphalerite	Hessite
Cerussite	Petzite
Limonite	Empressite

In addition to these there is no reasonable doubt but that a number of other minerals have been found, such as rhodochrosite, gray copper, cerargyrite and other oxides and carbonates. The character of the minerals changes greatly in passing from the surface down to the fourth level and below.

Empressite

Among the rather unusually numerous mineral species that have been identified as occurring in the Empress Josephine mine one is deserving of special attention because it turns out to be a species but recently recognized.

Mr. Frank Leavitt kindly presented to the writer a fragment of mineral that came from this mine and that was supposed to be a silver telluride. As this mineral did not closely resemble any recognized silver telluride it was thought worthy of special investigation. A quantitative chemical analysis was made by Mr. E. J. Dittus, Instructor in Metallurgy at the Colorado School of Mines, whose analysis appears below. After this analysis had been completed there appeared in the pages of the American Journal of Science the results of an independent investigation of this same mineral carried out in the mineralogical laboratry of the Sheffield School of Yale University by Mr. W. M. Bradley. The writer takes the liberty of quoting a portion of Mr. Bradley's paper[1], following his chemical analysis by that made by Mr. Dittus:

"Some years ago, what appeared to be a new mineral was found in the Empress-Josephine Mine in the Kerber Creek District of Colorado by Professor R. D. George of the University of Colorado. No analysis was made at that time, but qualitative tests were obtained which showed the presence of silver and tellurium. Several small specimens were recently sent to the writer for investigation. They were all massive in structure, careful inquiries having failed to locate any material showing crystal faces. The mineral occurs in very fine granular and compact masses associated with galena and native tellurium. It is metallic in luster, and gives a grayish black to black streak. The fracture is finely conchoidal to uneven, and upon such surfaces the color is a pale bronze. The mineral is brittle to friable, and has a hardness between 3 and 3.5. The specific gravity was determined as 7.510. In the oxidizing flame on charcoal it fuses at 1 giving a heavy white coating of tellumium dioxide and a black globule, which if placed in the reducing flame gives on cooling white dendritic points of silver on its surface. Prolonged heating in the oxidizing flame gives a globule of silver. In the open tube a faint white sublimate of tellumium dioxide is formed which if strongly ignited fuses to colorless globules. The mineral is readily soluble in hot dilute nitric acid."

Analysis by Bradley—

	I.	II.	Average.	Ratios.	
Insoluble	38	.39	.39		
Ag	45.16	45.17	45.17	.418	1.00
Te	54.62	54.89	54.75	.429 }	1.03
Fe	.30	.15	.22	.003 }	
	100.46	100.60	100.53		

Discussing this analysis, Mr. Bradley continues:

"From the analysis it will be seen that the mineral gives a ratio of practically Ag : Te : : 1 : 1, which fact points strongly to the conclusion that the formula AgTe represents a new mineral species. The name empressite has been given to it by Professor George on account of the fact that it was found in this particular mine." (Empress Josephine.)

1. Empressite, a New Silver-Tellurium Mineral from Colorado. Am. Jour. Sc. 4th Series, Vol. 38, Aug., 1914, pp. 163-165.

Analysis by Dittus—

	I.	II.	Average.	Ratios.	
Insoluble	.32	.34	.335		
Ag	43.71	43.68	43.695	.405	1.00
Te	53.86	53.81	53.835	.437	1.08
Fe	2.17	2.16	2.165	.038	
CaO	trace	trace	trace		
	100.06	99.99	100.03		

It will be observed that the analysis made by Mr. Dittus shows 2.165% Fe, corresponding to a molecular ratio of .038. If the Fe is considered as molecularly replacing Ag, as seems reasonable, and the corresponding molecular ratio is added to that of the Ag, we have

Molecular ratio of Ag .443
Molecular ratio of Te .437

or, Ag : Te : :: 1 : .99 This gives a ratio that is practically 1:1, being nearer to that than is the case with the analysis of Mr. Bradley.

Although this mineral is described in the above quoted article by Bradley as a new mineral species, this is not, however, the first time analyses of silver telluride have been published with a ratio approximately 1 : 1. Under the head of Hessite (Ag_2 Te) and Petzite (Ag, Au_2 Te) Hintze[1] publishes a list of analyses of silver, and of silver-gold tellurides that vary very greatly from Ag_2 Te to approximately Ag_1 Te, the gold and other bases when present being figured with the silver. In one case an analysas is given in which the ratio of silver to tellurium is even less than 1 : 1. In no case, however, does Hintze give an analysis in which the ratio between the silver and the tellurium is so close to 1 : 1 as is the case with the mineral from the Empress Josephine mine.

The mineral under discussion, while described as a new mineral species, is practically the same as that which figures as hessite in mineralogical literature.

Since the above was written there has appeared in "Chemical Abstracts,"[2] a brief abstract of a communication by Schaller[3]

1. Dr. Carl Hintze, Handbuch der Mineralogie, Vol. 1, p. 454, Leipsic, 1899.

2. R. S. McBride, Chem. Abs., Vol. 9, No. 1, Jan., 1915, p. 42.
3. Waldemar T. Schaller, The identity of empressite with muthmannite, J. Wash. Acad. 4, pp. 497-9, 1914.

in which attention is called to the fact that Bradley's empressite is "essentially pure muthmannite" (AgTe). The writer does not have access to the publication in which Mr. Schaller's article appears.

Ore-Values

It was not possible to obtain reliable information as to the ore-values of the Empress Josephine mine taken out during the period of its greatest activity. Through the kindness of Mr. Frank Leavitt the smelter returns on a few shipments of ore in the years 1908 and 1912 are available. These assays and analyses were made by the Ohio and Colorado Smelting and Refining Company.

Date.	Gross lbs.	Oz. Au	Oz. Ag	% Pb	% Cu	% Zn	% S	% Fe	% SiO_2	Net Value Per Ton	Treatment Per Ton
Apr. 1908	6300	.17	26.7	11.15		9.2	23.5	15.5	34.5	$7.96	$12.00
Apr. 1908	18040	1.67	12.6			4.5	8.1	6.1	73.0	26.10	13.00
Apr. 1908	4720	.055	54.6	23.9	.7	4.0	29.1	22.7	15.6	29.49	9.00
Apr. 1908	305	2.0	21.6	3.8		9.0	10.4	5.0	61.4	56.71	13.00
Apr. 1912	3257	1.225	46.9	25.4		7.9	12.0	7.8	36.0	60.00	12.85

In the above given statement the net value refers to the value per ton after subtracting from the gross value the treatment charges.

In addition to these smelter returns it may be of interest to add a few individual assays made by reliable commercial assayers on samples of the ore. No great value, however, can be attached to these assays as they do not represent, so far a known ore in shipping quantity.

Date—	Ore sample	Ozs. per ton Au	Ozs. per ton Ag	Per cent Te	Tot. value per ton
Jan. 1907	No. 1	0.64	159.80		$ 124.66
Jan. 1907	No. 2	0.06	40.50		29.55
Jan. 1907	No. 3	5.30	1282.70		1,003.89
Mar. 1907	Telluride ore	14.32	6465.00	48.50	4,747.25
June 1907		6.88	1622.50	(per cent Pb 39.7)	

It is evident that the fourth of the above given assays is that of a pure or nearly pure telluride, quite probably that of empressite in which silver is partly replaced by gold.

THE ST. LOUIS MINE

On the south side of Copper Gulch, about three-quarters of a mile above Bonanza and 100 feet above the valley bottom is located the Saint Louis mine (Plate I, in pocket, location 32, H3). This is a small mine that is owned by New York parties and is credited with having produced before 1913 a few thousand dollars forth of ore. During the winter of 1913 to 1914, while being worked by Tom Smith as lessee, some unusually rich gold ore was struck that excited no little interest in the camp. In the summer of 1914 the mine was being worked by a shaft 130 feet deep. The shaft is located in the center of the Saint Louis claim whose west end abuts against the east end of the Josephine claim.

Work has been done on three levels at respectively 50, 68 and 80 feet below the collar. On the first level 90 feet of drifting has been done, on the second level 40 feet. On the third level there are two independent leads or veins that have approximately parallel strikes but different dips. The strike of these two leads is N. 50° to 70° E. The shaft follows approximately the copper lead which dips 77° SE. The gold lead lies some ten or fifteen feet southeast of the copper lead at the 80-foot level and dips 55° NW. That is, the two leads dip towards each other, and, if they continue, should intersect each other not far below the 80-foot level.

The ore of the gold streak occurs in irregular stringers and bunches in the midst of a dark reddish jasper which is a replacement of the latite that forms the country rock. The material that carries the gold is soft and crumbly and is usually yellow stained, but may be black in spots. This material looks like yellow, clayey dirt. This gold lead has been drifted on for 300 feet. In addition the ore has been stoped out for a distance 20 feet long and 30 feet high.

The copper lead has a gangue that is also in part jaspery, but that tends toward coarse-grained quartz. Above the 80-foot level this lead shows considerable oxidation and carries lead and zinc sulphides, but no copper. Below the 80-foot level, as exposed in the shaft, there is good copper ore that carries in places 20% Cu. The copper ore consists of chalcopyrite and gray copper with a little bornite. This part of the ore is hard and contains more or less crystalline quartz, but is not free from jasper. The copper vein has not been developed at all below the 80-foot level so that its extent and value is problematical.

The following smelter returns are from the records of the Ohio and Colorado Smelting and Refining Company at Salida, Colo., to whom some of this ore was sent. The first three are from the gold lead, the last from the copper vein. By the term "net values" is meant the values after paying smelter charges, but not haulage.

Smelter Returns—

	Net lbs.	Ounces Au.	Ounces Ag.	Per cent lead.	Net value per ton.
Dec. 1, 1913..	20,034	3.715	22.3	8.0	$ 70.10
Feb. 16, 1914..	36,122	3.73	14.4	10.75	76.36
Feb. 16, 1914..	28,860	7.10	20.8	9.0	145.60
Dec. 20, 1913..	43,458	1.3	5.95	5.1	22.16

OTHER MINES

A few other mines and prospects have been opened up in Copper Gulch, none of which appear to have produced much, and none of which are accessible. One of the most promising is the Hortense, located on the road at the bottom of the gulch, about half-way between the Empress Josephine and the Saint Louis. This mine is situated on a vein of similar nature to the Josephine vein and running parallel to it on the south side. About $2,000 worth of ore has been produced.

MINES OF THE MANGANESE BELT

DESCRIPTION OF BELT

Manganese minerals, more especially rhodochrosite, are sparingly developed in all parts of the Bonanza district. Mention has been made of their having been observed in the Rawley, Antoro, Bonanza, and other veins, but always very sparingly. On the mountain above the Antoro mine on the north side of Rawley Gulch appears a narrow belt carrying mananese oxides, mostly in the form of psilomelane. This belt is about 4,000 feet long, extends in a general northeast and southwest direction, and has an apparent width of 30 or 40 feet. No mines have been opened in this belt but prospect holes and shafts disclose the nature of the material. With the psilomelane occur limonite and kaolinite; also some manganite. Many other prospects and mines that have not been described in this report because of lack of information are scattered over the district and in numerous cases show small amounts of manganese minerals on the rock dumps.

In speaking of the mines of the manganese belt, therefore, it is not intended to intimate that manganese minerals are limited in their distribution to a particular part of the territory under consideration. It is true, however, for a limited part of the district that manganese minerals are extremely abundant and form a very large part or even the greater part of the gangue. The manganese belt embraces an area about a mile wide crossing Eagle Gulch in a general north and south direction. How far north of Eagle Gulch it extends is not known as prospects are not very numerous in this direction; but such prospects and mines as have been developed indicate the extension of a belt containing abundant manganese across the head of Copper Gulch and probably to and beyond the head of Rawley Gulch. To the south the belt is known to extend several miles beyond the bounds of the area investigated. One or two mines have been opened in this southern extension, one of which, the Express mine, is situated about three miles south of Eagle Gulch. The most important properties within the bounds of this manganese belt are the Eagle mine and the Oregon tunnel, both situated in Eagle Gulch.

THE EAGLE MINE

History and Development

The Eagle mine is located in Eagle Gulch a little over half a mile above the junction of the gulch with Kerber Creek. In point of output this mine is the third in importance in the district, as it is understood to have produced ore to the value of $250,000. The mine is owned by D. I. Whiteman. It was opened in 1880 but was not worked much until about 1898 or 1899. It was then worked continuously up to 1906 when it was closed down. It has not been opened since that date.

The mine is worked through a shaft that has been sunk on the common end line of two claims, the Eagle and the Hawk. The shaft is 500 feet deep. There are nine levels at varying distances, with more or less drifting on each level as shown below:

70-foot level..............amount of drifting 25 feet
100-foot level..............amount of drifting 30 feet
150-foot level..............amount of drifting 90 feet
200-foot level..............amount of drifting 450 feet
250-foot level..............amount of drifting 257 feet

300-foot level..............amount of drifting 175 feet
350-foot level..............amount of drifting 450 feet
400-foot level..............amount of drifting 350 feet
500-foot level..............amount of drifting 400 feet

Most of the levels have been stoped out and the stopes filled with waste rock or low grade ore. The writer was informed by Mr. Dan Mahoney of Bonanza that these stope fillings will run from 15 to 20 ounces in silver.

The vein strikes NW. and dips NE., but, as the mine was filled with water, the angle of strike and dip could not be taken. The mine was evidently well equipped when running. There are a dozen or more buildings, including cabins for dwellings, but of the equipment nothing remains but a cylindrical drum hoist and two fire-tube boilers.

The Eagle Ore

MINERALS—

The Eagle ore is unusually beautiful from an esthetic point of view. Portions of the ore display unusual beauty owing to a most attractive combination of crystallized rhodochrosite and green fluorite and of white crystallized quartz. The following minerals have been observed in this ore:

Quartz	Native silver
Rhodochrosite	Galena
Fluorite	Pyrite
Psilomelane	Chalcopyrite
Sphalerite	

Quartz, rhodochrosite and fluorite together make up nearly the entire bulk of the ore. Probably quartz is the most abundant of the three. Certainly fluorite is the least abundant, but they fluctuate greatly in relative importance. In places the manganese carbonite is not only the most important gangue mineral but it may even make almost solid masses weighing many pounds. In this respect it is in strong contrast to the same mineral as it occurs in the mines outside of this manganese belt.

The ore upon the whole is extremely porous or cellular. Quartz forms more or less continuous masses of milky white color, but it is very irregular in its distribution and is invariably filled with ragged cavities and pores that are partially or completely filled with the other gangue- and ore-minerals. Quartz also forms small, sharp, prismatic crystals perched upon the rhodochrosite in the vugs. This latter manner of occurrence is exceptional.

Rhodochrosite is invariably crystallized except in the larger, pure masses where it forms coarsely granular aggregates. It occurs in light to deep pink, mostly warped rhomboheadrons that fill and line nearly all the cavities. These rhombohedral crystals vary in size from a millimeter to three-quarters of an inch. In many cases the surface color is changed to brownish due to the deposition of a thin film of limonite. This limonite film is easily removed by immersion in concentrated hydrochloric acid without damage to the specimen.

The fluorite is of a deep green color and contrasts very beautifully with the pink rhodochrosite. The crystals appear to be rough octahedrons. The octahedral crystals, however, are composite crystals built up of a multitude of parallel-growing, smaller crystals, whose real forms are the cube modified by the dodecahedron.

All the other mineral constituents of this ore form a very small part of the bulk or weight. Sphalerite is the most abundant and varies in color from yellow to nearly black. Pyrite, which is so very abundant in the other ores of the district, is almost entirely absent. Galena and chalcopyrite form so small a part of the ore as hardly to figure in the values. The ore values are almost entirely in silver. This occurs native in the form of delicate wire silver. The silver wires and threads occur intimately intergrown with the sulphides, especially with the sphalerite and galena.

Ore Values—

Complete assays of this ore are not available. But the following assays, furnished by Mr. D. I. Whiteman, the owner of the mine, gives the silver and the gold content. With a few exceptions the gold values are nearly neligible.

Assays of the Eagle ore—

Date.	Ounces, Ag.	Ounces, Au.
April, 1901	95.9	.12
April, 1902	205.7	.32
April, 1903	92.0	.27
Sept., 1901	103.2	1.25
June, 1904	189.3	1.02
Jan., 1905	100.2	....
Feb., 1905	75.5	.05
April, 1905	95.2	....

July, 1905	137.7	....
Aug., 1905	35.6	....
Aug., 1905	124.5	.09
Oct., 1905	227.4	.08
Nov., 1905	108.1	.06
Dec., 1905	136.0	.07

As a further indication of the character of this ore an analysis of a sample made July 28, 1905. It is not known whether this was a fairly typical sample or not. It evidently contained much more rhodochrosite than all the other minerals combined.

Analysis of Eagle ore—

Ag	SiO_2	Fe	Mn	Zn	S
58 7/8 oz.	12.8	2.6	30	3.2	2.2

THE OREGON TUNNEL

Near the upper end of Eagle Gulch a vein has been opened through a tunnel known as the Oregon tunnel. The property is owned by the Croatian Mining and Development Company, E. Kesserich, Sept. (Plate I, in pocket, location 6, K4). This property was not seen by the writer who is dependent on the report made by two student members of the party.

The vein strikes N. 81° W. and dips 72° N. The vein occupies a brecciated zone some 65 feet wide in the latite which forms the country rock. It contains quartz, rhodochrosite and psilomelane. The latter really forms the ore as gold and silver values are very low. The highest silver values found are said to be seven ounces. Analyses were made on samples taken as follows: No. 1 from the dump; Nos. 2 and 3 from the vein; No. 4 from the same vein exposed in a tunnel 100 yards from the main tunnel.

Analyses of Ore from the Oregon Tunnel—

No.	Ounces Au	Ounces Ag	Per cent SiO_2	Per cent Mn
1	.02	1.44	55.0	9.8
2	..	1.20	58.1	8.0
3	..	1.32	39.9	13.8
4	..	1.48	68.0	10.3

Although the writer was not able to investigate the Oregon Tunnel property personally, it would seem that there is a very considerable vein in which pyrolusite is very abundant. This manganitic oxide is undoubtedly formed by the attack of the oxydizing surface waters on the rhodochrosite, or manganese carbonate of the original vein. There is a very general feeling among miners of Colorado that the presence of manganese makes for good ore, and this feeling is borne out very largely by the facts. Van Hise[1] calls attention to this in connection with a discussion of the importance of manganese in the precipitation of ores, and calls attention to the association of rich gold ore or of gold-silver ore at the Campbird and Golden Fleece mines and at Rico, all in the San Juan Mountain district, Colorado.

That the Eagle mine carries high values in silver and very considerable quantities of gold would naturally lead one to expect similar values in other manganese veins of the district, and such doubtless were the expectations of those who opened the manganiferous vein of the Oregon Tunnel. Whatever may be the case with silver it is more than possible that enriched gold deposits may be struck in this property at the lower limit of the psilomelane belt.

A very interesting as well as suggestive light on the action of manganese oxides in the solution and precipitation of gold is to be found in a paper by W. H. Emmons[2] read before the American Institute of Mining Engineers. Emmons shows that in the upper portions of manganese-bearing veins gold is dissolved by descending water through the agency of nascent chlorine which is liberated by manganitic compounds, such as psilomelane, and is carried down to lower levels. As long as sufficient oxygen is present to prevent the formation of ferrous sulphate, or to oxydize the ferrous sulphate first formed to ferric sulphate, no gold can be precipitated; but at a lower level the pyrite present would be oxydized to ferrous sulphate which will precipitate gold from the gold chlorite solution, and cause an enrichment of gold at that point.

As applied to the ore cf the Oregon Tunnel, at the level where abundant psilomelane is found one should expect an impoverishment of the gold content. But if gold was originally present, as is the case with the Eagle mine ore, one should look for it below the level of the psilomelane.

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1. Van Hise, Charles R., A treatise on metamorphism, U. S. Geol. Survey, Mon. 47, 1904, p. 1115.

2. Emmons, W. H., Agency of manganese in the superficial alteration and secondary enrichment of gold deposits of the United States, Am. Inst. Min. Eng., Trans., Vol. 42, pp. 3-73, 1912. Also reprinted in book form, entitled Ore Deposits, Am. Inst. Min. Eng., 1913.

ORIGIN OF THE ORES OF THE BONANZA DISTRICT

In practically all the properties of this district that may be rated as more than mere prospects the oxydized upper portion of the veins, in so far as such oxydized parts existed, have almost invariably been worked out and the workings abandoned and caved in. An actual examination, therefore, of the oxydized ores has not been possible, and such information as could be obtained at this late date was vague and unsatisfactory. Apparently, however, part of the high values of the early days of the camp are to be attributed to the oxydized ores of lead and silver, in the form mainly of cerussite and cerargyrite.

The origin of this upper part of the vein in which the original sulphides have been changed to oxides and the latter precipitated in greatly enriched form is now well known. The conditions do not differ materially in the Bonanza District from what are met with in most other mining regions of the Cordilleran west. The main interest lies in the condition of the veins in the sulphide belt below the oxides, for upon this depends the life of the camp.

Information on this matter is not very abundant for the reason that there has been so very little attempt to open up ore bodies far below the surface, and but little opportunity has been afforded to study the change in the ore bodies with increasing depth. In this matter we are limited largely to the ore vein of the Rawley vein. It has already been stated that, so far as the lead-silver-copper veins are concerned—that is, those veins outside of the manganese belt,—a very general tendency is observable for an increase of the copper and for a loss of the lead with increasing depth; so that the ores incline to change character from a lead-silver or a lead-silver-copper ore on the surface to a silver-copper ore in the depth, as particularly demonstrated in the Rawley mine. Is this change in character due to alteration of the original sulphide ore veins or is the distribution of the metals due to primary causes? There is no good reason to believe that the Rawley vein, so far as its manner of formation and of its subsequent alteration by secondary agencies are concerned, is materially different from that of most of the other veins. At any rate we are obliged to judge of the rest by what we are able to learn of the better developed Rawley vein.

In the description of this vein it has already been pointed out that the minerals that compose the vein, including even the lead sulphide, galena, are primary, and are not to be accounted for by the effect of descending waters acting upon original leaner sulphides; and that the change in character of the ore with depth must be explained by a zonal deposition of the different sulphides, due, most probably, to variations in pressure and temperature of the rising vein waters. This assumption, should later developments prove it to be well founded, is of great importance in that it argues for the continuance of the veins to considerable depths with the chances in favor of greater rather than lesser values as the mine deepens. A vein, therefore, that carries commercially available ore at or near the surface, may reasonably be expected to continue to yield equally good or better ore at lower depths.

As to the ores of the manganese belt, the data are too meager to permit any assumption as to their character in the depth. There is, however, no sufficient reason to assume that they are essentially different from the other veins, in as much as manganese minerals, mostly rhodochrosite, occur to a greater or less extent in all the veins. As stated in connection with the description of the Oregon Tunnel, wherever a large body of manganese oxide occurs it would be well to prospect for gold below the oxide deposit.

There is undoubtedly a genetic connection between the igneous rocks of the district and the ore bodies as is now generally accepted for similar sulphide ore veins in Colorado and the Cordilleran west. The ores occur in the Bonanza latite, the Eagle Gulch latite, and the andesite, but not in the rhyolite, and may, perhaps, have been deposited by magmatic waters escaping from the magma that yielded these igneous rocks.

SUPPLEMENT

LIST OF MINING CLAIMS IN ALPHABETICAL ORDER

Survey No.	Name	Section	Township	Range
1332	Ajax	17	47	8
16861	Alice	24	47	7
1388	American Eagle	17	47	8
939	Am. Mammoth	30	47	8
802	Am. Revenue	24	47	7
937	Antoro	18	47	8
14183	Artic	18	47	8
7820	Atlantic	19	47	8
1459	Aurora	24	47	7
13598	Bachus	30	47	8
15099	Baltimore	24	47	7
15099	Baltimore No. 2	24	47	7
14672	Bay State	30	47	8
1154	Beaver	25	47	7
1321	Big Manitou	17	47	8
19582	Black Bess	24	47	7
1052	Bob Burdette	20	47	8
18775	Bonanza	24	47	7
614	Bonanza	24	47	7
13598	Bonaparte	30	47	8
2291	Boston	23	47	7
14672	Boston	30	47	8
14845	Botha	30	47	8
16744	Brighton	18	47	8
18824	Brooklyn	7	47	8
14347	Buffalo	17	47	8
19033	Burns	19	47	8
17834	Cabin	18	47	8
1624	Camp Bird	18	47	8
965	Carrie Eugene	7	47	8
8524	Chicago	30	47	8
18392	Chicago No. 8	17	47	8
18392	Chicago No. 11	17	47	8
14672	Chief	30	47	8
2267	Cincinnati	24	47	7
13597	Cliff	30	47	8
19144	Cobalt	24	47	7
18775	Cocomongo	24	47	7
13597	Coin	30	47	8
13598	Columbus	30	47	8
1348	Columbus	17	47	8
19554	Continental	18	47	8
6014	Cora	18	47	8
7515	Coronet	18	47	8

Survey No.	Name	Section	Township	Range
19554	Crackerjack	8	47	8
1502	Crain Boy	30	47	8
19144	Crescent	24	47	7
19144	Crescent No. 2.............	24	47	7
19144	Cretone	24	47	7
19144	Crevet	24	47	7
14845	Cronje	30	47	8
1786	Crown Point	18	47	8
19554	Dandy	8	47	8
591	Defiance	25	47	7
1016	Demming	18	47	8
1024	De Sota	25	47	7
19554	Divide	18	47	8
1221	Durango	17	47	8
1319	Emma	17	47	8
625	Empress Josephine	30	47	8
14347	Enness F	18	47	8
14347	Equalizer	18	47	8
13580	Erie	19	47	8
15541	Esther	18	47	8
19033	Ethelyn	19	47	8
7283	Excelsior	25	47	7
6424	Exchequer	24	47	7
5358	Fair Play	7	47	8
1391	59er	24	47	7
15513	Foster	18	47	8
927	Four Per Cent	7	47	8
18825	Golden Age	7	47	8
1931	Golden Fleece	19	47	8
7699	Gem City	18	47	8
6016	General Hancock	18	47	8
2190	Glenbrook	30	47	8
16744	Glennevis	18	47	8
1320	Grand View	17	47	8
19554	Great Depth	8	47	8
19554	Great Depth No. 2	8	47	8
2304	Great Eastern	24	47	7
14347	Great Mogul	17	47	8
1349	Green Bay	17	47	8
17738	Grover Cleveland	24	47	7
15541	Gypsy Queen	18	47	8
14348	Hanover	19	47	8
7515	Helen Segar	18	47	8
1025	Horace	25	47	7
909	Hortense	30	47	8
15499	Hyde	18	47	8
14183	Ignacio	18	47	8
945	Illinois	30	47	8

Survey No.	Name	Section	Township	Range
14183	Independence	18	47	8
7152	Iroquois	7	47	8
1350	Itasca	8	47	8
14845	Joubert	30	47	8
1364	June	18	47	8
17251	Jupiter	18	47	8
16861	Juretta	24	47	7
6036	Katie	8	47	8
666	Keystone	24	47	7
14845	Kruger	30	47	8
1583	Last Chance	19	47	8
966	Lawrence	19	47	8
6013	Legal Tender	7	47	8
19532	Lincoln	18	47	8
771	Little Jennie	18	47	8
2265	Little Jersey	24	47	7
1351A	Little Manitou	17	47	8
1351B	Little Manitou Mill Site	17	47	8
1686	Little Pittsburg	24	47	7
19144	Lone Star	24	47	7
13570	Mariposa	30	47	8
14998	May	20	47	8
15541	May Queen	18	47	8
17178	Memphis	24	47	7
1101	Merrimac	18	47	8
7837	Michigan	18	47	8
15719	Midget	18	47	8
6015	Midnight	7	47	8
12281	Mill Site	18	47	8
1503	Minehart	19	47	8
594	Mineral King	25	47	7
17148	Minnie Lynch	19	47	8
15248	Mountain Chief	20	47	8
16744	Mount Joy	18	47	8
613	Nettie	24	47	7
2290	New York	24	47	7
1416	Norah	7	47	8
14183	North Pole	18	47	8
1933	Ontario	19	47	8
15951	Ophir	30	47	8
14183	Orphan Belle	18	47	8
14183	Ouray	18	47	8
733	Paragon	18	47	8
14584	Park	19	47	8
14584	Park	18	47	8
787	Payson	18	47	8
14183	Peary	18	47	8
2266	Philadelphia	24	47	7

Survey No.	Name	Section	Township	Range
13597	Philadelphia	30	47	8
1585	Plato	20	47	8
15951	Portland	30	47	8
938	Poverty	18	47	8
18825	President	7	47	8
1299	Pride of the West	7	47	8
17850	Pueblo	8	47	8
17850	Pueblo	8	47	8
15248	Queen City	20	47	8
616	Radcliff	7	47	8
1121	Rainbow	17	47	8
980	Rawley	18	47	8
1020	Red Buck	25	47	7
14183	Red Cloud	18	47	8
1584	Rosa Lee	19	47	8
1554	Rover	20	47	8
15541	Ruth	18	47	8
16568	Saint Joseph	25	47	7
8524	Saint Louis	30	47	8
1586	San Joquin	19	47	8
1590	Sarah D	24	47	7
16306	Senator	19	47	8
16306	Senator No. 2	19	47	8
14183	Shavano	18	47	8
18791	Simonds	19	47	8
15248	Sixteen to One	20	47	8
2548	Sosthenes	18	47	8
15248	Southern Bay	20	47	8
2593	Specie Payment	7	47	8
14586	Stem Winder	20	47	8
14347	Success	18	47	8
14672	Summit	30	47	8
19554	Timberline	18	47	8
14689	Tip Top	18	47	8
14689	Townsend	18	47	8
18611	Vintah	18	47	8
1410	Vallejo	18	47	8
18825	Vice-President	7	47	8
18825	Vini-Vidi-Vici	7	47	8
18791	Wainright	19	47	8
14183	Washakee	18	47	8
19532	Washington	18	47	8
18792	West Rawley	18	47	8
7228	Whale	18	47	8
597A	Wheel of Fortune	25	47	7
598	Wide Awake	25	47	7
1308	Yellow Type	7	47	8
14689	Zero	18	47	8

LIST OF MINING CLAIMS NUMERICALLY ARRANGED

Survey No.	Name	Section	Township	Range
591	Defiance	25	47	7
594	Mineral King	25	47	7
597A	Wheel of Fortune	25	47	7
598	Wide Awake	25	47	7
613	Nettie	24	47	7
614	Bonanza	24	47	7
616	Radcliff	7	47	8
625	Empress Josephine	30	47	8
666	Keystone	24	47	7
733	Paragon	18	47	8
771	Little Jennie	18	47	8
787	Payson	18	47	8
802	Am. Revenue	24	47	7
909	Hortense	30	47	8
927	Four Per Cent	7	47	8
937	Antoro	18	47	8
938	Poverty	18	47	8
939	Am. Mammoth	30	47	8
945	Illinois	30	47	8
965	Carrie Eugene	7	47	8
966	Lawrence	19	47	8
980	Rawley	18	47	8
1016	Demming	18	47	8
1020	Red Buck	25	47	7
1024	De Sota	25	47	7
1025	Horace	25	47	7
1052	Bob Burdette	20	47	8
1101	Merrimac	18	47	8
1121	Rainbow	17	47	8
1154	Beaver	25	47	7
1221	Durango	17	47	8
1299	Pride of the West	7	47	8
1308	Yellow Type	7	47	8
1319	Emma	17	47	8
1320	Grand View	17	47	8
1321	Big Manitou	17	47	8
1332	Ajax	17	47	8
1348	Columbus	17	47	8
1349	Green Bay	17	47	8
1350	Itasca	8	47	8
1351A	Little Manitou	17	47	8
1351B	Little Manitou Mill Site	17	47	8
1364	June	18	47	8
1388	American Eagle	17	47	8
1391	59er	24	47	7
1410	Vallejo	18	47	8

Survey No.	Name	Section	Township	Range
1416	Norah	7	47	8
1459	Aurora	24	47	7
1502	Crain Boy	30	47	8
1503	Minehart	19	47	8
1554	Rover	20	47	8
1583	Last Chance	19	47	8
1584	Rosa Lee	19	47	8
1585	Plato	20	47	8
1586	San Joquin	19	47	8
1590	Sarah D	24	47	7
1624	Camp Bird	18	47	8
1686	Little Pittsburg	24	47	7
1786	Crown Point	18	47	8
1931	Golden Fleece	19	47	8
1933	Ontario	19	47	8
2190	Glenbrook	30	47	8
2265	Little Jersey	24	47	7
2266	Philadelphia	24	47	7
2267	Cincinnati	24	47	7
2290	New York	24	47	7
2291	Boston	23	47	7
2304	Great Eastern	24	47	7
2548	Sosthenes	18	47	8
2593	Specie Payment	7	47	8
5358	Fairplay	7	47	8
6013	Legal Tender	7	47	8
6014	Cora	18	47	8
6015	Midnight	7	47	8
6016	General Hancock	18	47	8
6036	Katie	8	47	8
6424	Exchequer	24	47	7
7152	Iroquois	7	47	8
7228	Whale	18	47	8
7283	Excelsior	25	47	7
7515	Coronet	18	47	8
7515	Helen Segar	18	47	8
7699	Gem City	18	47	8
7820	Atlantic	19	47	8
7837	Michigan	18	47	8
8524	Chicago	30	47	8
8524	Saint Louis	30	47	8
12281	Mill Site	18	47	8
13570	Mariposa	30	47	8
13580	Erie	19	47	8
13597	Coin	30	47	8
13597	Cliff	30	47	8
13597	Philadelphia	30	47	8
13598	Bachus	30	47	8

Survey No.	Name	Section	Township	Range
13598	Bonaparte	30	47	8
13598	Columbus	30	47	8
14183	Arctic	18	47	8
14183	Ignacio	18	47	8
14183	Independence	18	47	8
14183	North Pole	18	47	8
14183	Orphan Belle	18	47	8
14183	Ouray	18	47	8
14183	Peary	18	47	8
14183	Red Cloud	18	47	8
14183	Shavano	18	47	8
14183	Washakee	18	47	8
14347	Buffalo	17	47	8
14347	Enness F.	18	47	8
14347	Equalizer	18	47	8
14347	Great Mogul	17	47	8
14347	Success	18	47	8
14348	Hanover	19	47	8
14584	Park	18	47	8
14584	Park	19	47	8
14586	Stem Winder	20	47	8
14672	Bay State	30	47	8
14672	Boston	30	47	8
14672	Chief	30	47	8
14672	Summit	30	47	8
14689	Tip Top	18	47	8
15689	Townsend	18	47	8
14689	Zero	18	47	8
14845	Botha	30	47	8
14845	Cronje	30	47	8
14845	Joubert	30	47	8
14845	Kruger	30	47	8
14998	May	20	47	8
15099	Baltimore	24	47	7
15099	Baltimore No. 2	24	47	7
15248	Mountain Chief	20	47	8
15248	Queen City	20	47	8
15248	Sixteen to One	20	47	8
15248	Southern Bay	20	47	8
15499	Hyde	18	47	8
15513	Foster	18	47	8
15541	Esther	18	47	8
15541	Gypsy Queen	18	47	8
15541	May Queen	18	47	8
15541	Ruth	18	47	8
15719	Midget	18	47	8
15951	Ophir	30	47	8
15951	Portland	30	47	8

Survey No.	Name	Section	Township	Range
16306	Senator	19	47	8
16306	Senator No. 2	19	47	8
16568	Saint Joseph	25	47	7
16744	Brighton	18	47	8
16744	Glennevis	18	47	8
16744	Mount Joy	18	47	8
16861	Alice	24	47	7
16861	Juretta	24	47	7
17148	Minnie Lynch	19	47	8
17178	Memphis	24	47	7
17251	Jupiter	18	47	8
17738	Grover Cleveland	24	47	7
17834	Cabin	18	47	8
17850	Pueblo	8	47	8
17850	Pueblo No. 2	8	47	8
18392	Chicago No. 8	17	47	8
18392	Chicago No. 11............	17	47	8
18611	Vintah	18	47	8
18775	Bonanza	24	47	7
18775	Cocomongo	24	47	7
18791	Simonds	19	47	8
18791	Wainright	19	47	8
18792	West Rawley	18	47	8
18824	Brooklyn	7	47	8
18825	Golden Age	7	47	8
18825	President	7	47	8
18825	Vice President	7	47	8
18825	Vini-Vidi-Vici	7	47	8
19033	Burns	19	47	8
19033	Etheyln	19	47	8
19144	Cobalt	24	47	7
19144	Crescent	24	47	7
19144	Crescent No. 2.............	24	47	7
19144	Cretone	24	47	7
19144	Crevet	24	47	7
19144	Lone Star	24	47	7
19532	Lincoln	18	47	8
19532	Washington	18	47	8
19554	Continental	18	47	8
19554	Crackerjack	8	47	8
19554	Dandy	8	47	8
19554	Divide	18	47	8
19554	Great Depth	8	47	8
19554	Great Depth No. 2	8	47	8
19554	Timberline	18	47	8
19582	Black Bess	24	47	7

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COLORADO STATE GEOLOGICAL SURVEY
R. D. GEORGE, STATE GEOLOGIST

Geology by Horace B. Patton.
Surveyed in 1912 and 1913.

MAP SHOWING THE TOPOGRAPHY AND GEOLOGY OF THE BONANZA DISTRICT, SAGUACHE COUNTY, COLORADO

Triangulation and Topography by G. Montague Butler, Roy F. Smith, and Horace B. Patton with the assistance of Students of the Colorado School of Mines. Surveyed in 1912.

Scale $\frac{1}{24000}$ approximately 2000 feet to the inch

0 ¼ ½ ¾ 1 2 Miles

0 ½ 1 2 Kilometers

Contour interval 100 feet
Datum is mean sea level

ROCKY MOUNTAIN BANK NOTE CO

LEGEND

ar — Archean
Mostly greenish black massive amphibolite. Also muscovite-biotite schist. In one place a massive grayish hornblende-augite monzonite.

qal — Quarternary, Alluvium
Fine gravel, sand and silt. Found only in the Kerber Creek valley.

Tertiary Eruptives

bl — Bonanza Latite
Usually gray, grayish black when fresh, sometimes brown, fine grained with phenocrysts of feldspar and often of biotite. Marked cleavage due to flow structure frequent. Invariably some angular, mostly very small, inclosed fragments of gray, black, and brown colored andesite. In places thickly crowded with same.

egl — Eagle Gulch Latite
A gray massive rock with fine grained groundmass and usually recognizable phenocrysts of orthoclase, also smaller plagioclase phenocrysts. Shows quartz under the microscope.

hpl — Haydens Peak Latite
A fine grained, brownish gray, massive rock with minute, inconspicuous feldspar phenocrysts. Never fresh. Contains quartz in groundmass. Only on Haydens Peak.

hbl — Hornblende-Biotite Latite
Usually a very dark or black rock with fine grained groundmass which under the microscope shows hyalopilitic texture. Contains visible phenocrysts of black prisms of hornblende and brown to black biotite.

dl — Dike Latite
Fine grained, gray rocks, with a few visible and good sized quartz phenocrysts, well rounded. Only in dikes.

rh — Rhyolite
Very light colored to nearly white rocks of fine grain, sometimes showing fresh orthoclase phenocrysts and a very few black biotite crystals. Also glassy, yellow to brown pitchstones.

a — Andesite
Mostly gray to black augite andesites, showing phenocrysts of plagioclase but not of augite, locally amygdaloidal. Also some biotite andesite with visible biotite phenocrysts. Also breccias or tuffs these rocks.

Dip and Strike

Important triangulation stations shown as a triangle followed by a number.

Houses, shaft houses and mines shown thus: ▪ ▬

Shafts without shaft house shown thus: ▫

Prospects shown thus: ×

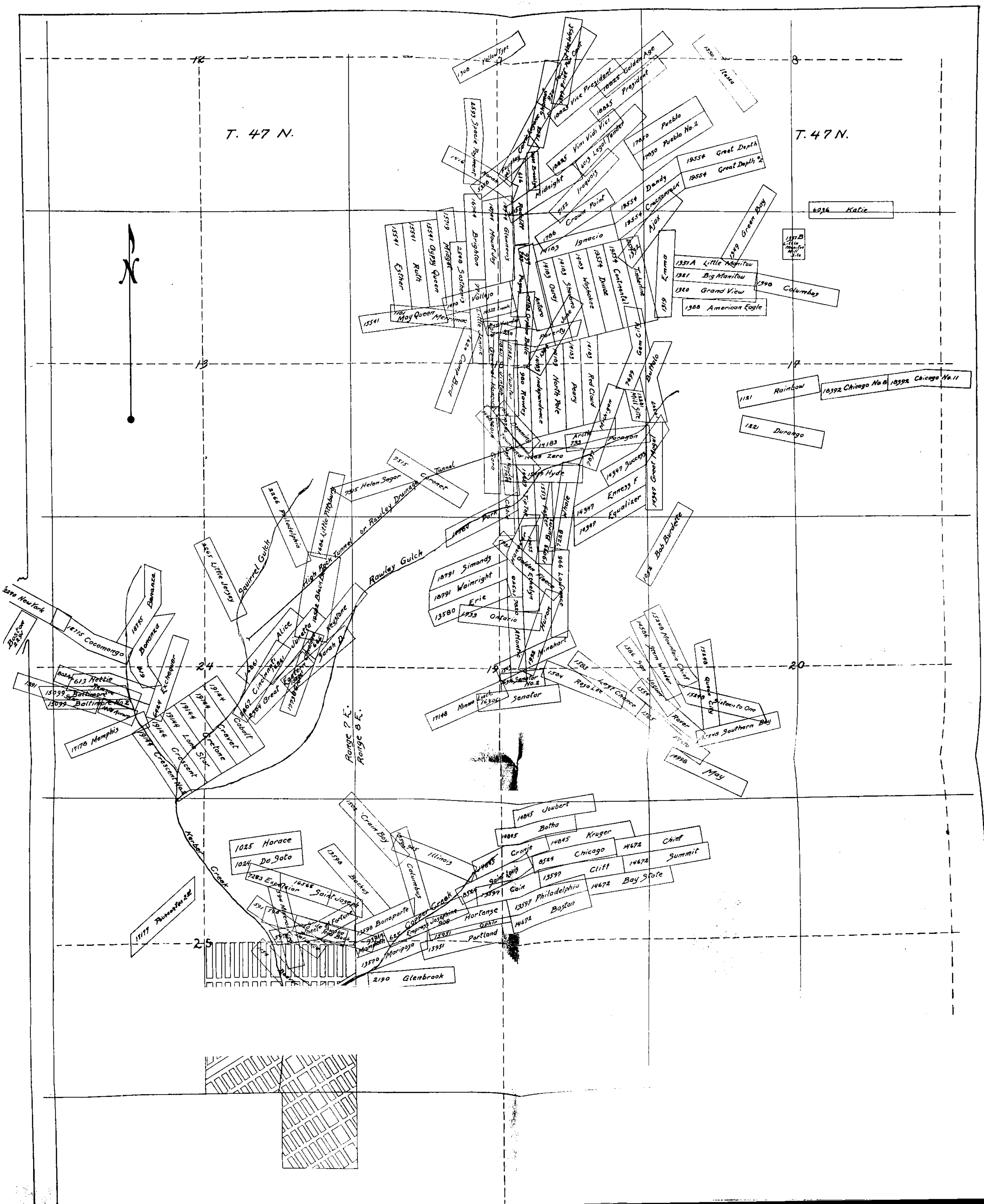
Tunnels shown thus: Y

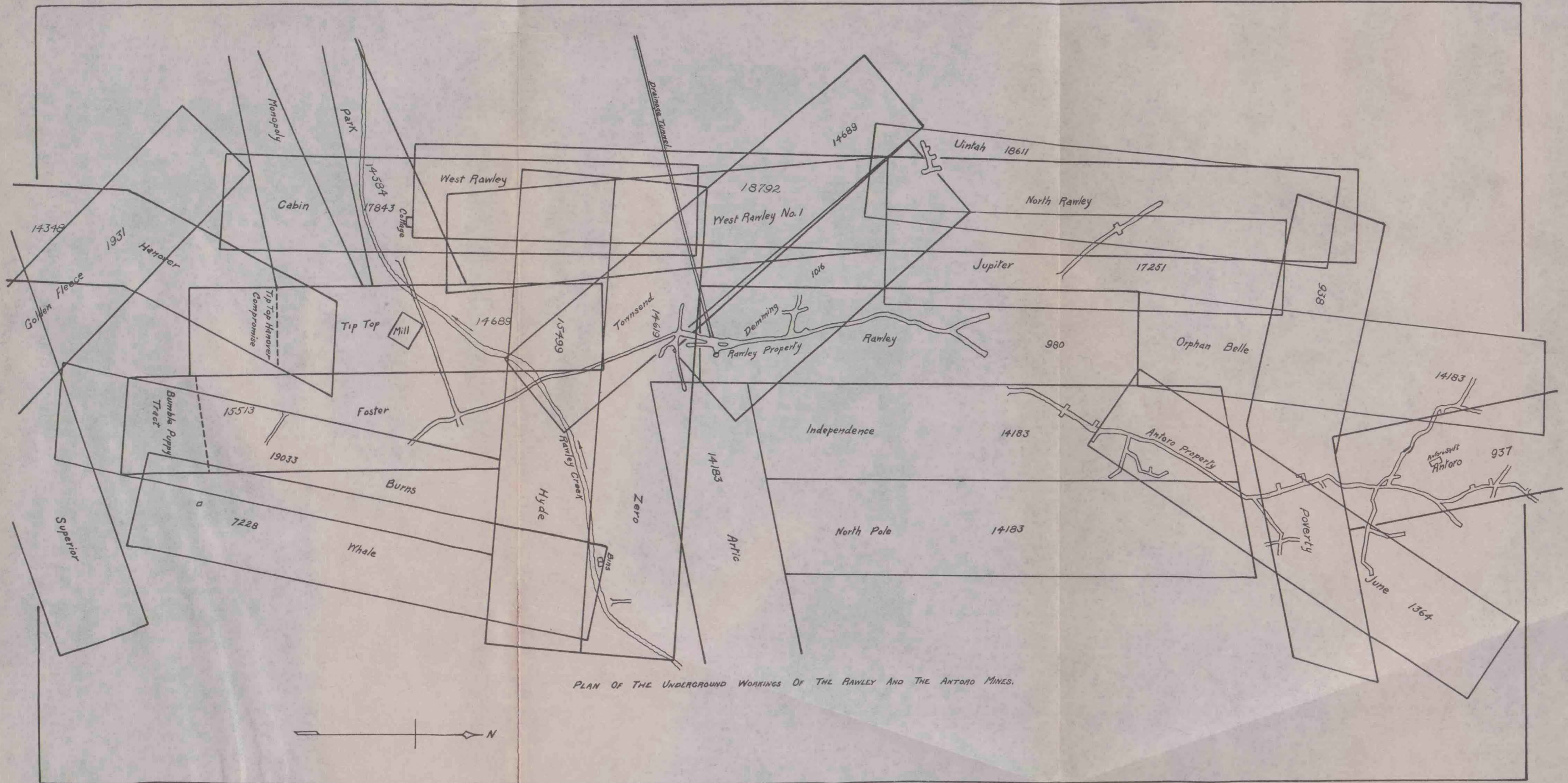
Good roads thus: ═══

Poor roads, often impassible for wagons thus: ┈┈┈

LIST OF MINES

	Mine	Location
1.	Bonanza	F2
2.	Hoodo lode	F2
3.	Shawmut	C4
4.	May Belle	C3
5.	Eagle	L3
6.	Oregon tunnel	K4
7.	Vienna	C3
8.	Sosthenes	D3
9.	Bradbury claims	D2-C3
10.	Rawley	E3
11.	Antoro tunnel	E3
12.	Antoro shaft	D3
13.	Empress Josephine	H3
14.	Exchequer	G2
15.	Cocomongo	F2
16.	Memphis or Arkansas	G2
17.	Black Bess	F3
18.	Peterson tunnel	K3
19.	Paragon	E2
20.	Whale	F3
21.	Superior	F3
22.	Hortense	H3
23.	Saint Joseph	H2
24.	Pochahontas	H2
25.	Hanover	F3
26.	Michigan	E4
27.	Gem City	E4
28.	Cora	E3
29.	Legal Tender	C4
30.	Minnie Lynch	G3
31.	Coronet	E3
32.	Saint Louis	H3
33.	Rainbow	E4
34.	Great Mogul or First Chance	E4
35.	Cornucopia	F2
36.	Keystone	F3
37.	Little Jenny	D3
38.	Payson	D3
39.	Revenue	G2
40.	Rawley drainage tunnel	F2


T. 47 N.
T. 47 N.
Range 7 E.
Range 8 E.
Squirrel Gulch
Rawley Gulch
High Rock Tunnel or Rawley Drainage Tunnel
Kerber Creek
Copper Creek
Yellow Type
Vice President
Golden Age
President
Pueblo
Pueblo No. 2
Great Depth
Great Depth No. 2
Vini Vidi Vici
Legal Tender
Midnight
Iroquois
Crown Point
Dandy
Crackerjack
Ajax
Green Bay
Katie
Ignacio
Esther
Ruth
Ouray Queen
Midget
Brighton
Vallejo
May Queen
Merrimac
Little Manitou
Big Manitou
Grand View
American Eagle
Columbus
Emma
Gem City
Buffalo
Red Cloud
Peary
North Pole
Independence
Rawley
Rainbow
Chicago No. 8
Chicago No. 11
Durango
Paragon
Zero
Hyde
Coronet
Helen Sagor
Little Pittsburg
Philadelphia
Little Jersey
Equalizer
Bob Burdette
Simonds
Wainright
Erie
Ontario
Golden Fleece
Atlantic
Senator
Roya Lee
Last Chance
Mountain Chief
Sixteen to One
Southern Bay
May
Bonanza
New York
Cocamongo
Boston
Nettie
Baltimore
Baltimore No. 2
Memphis
Excalibur
Crescent
Lone Star
Gretone
Cravet
Cobalt
Cincinnati
Alice
Juanita
Keystone
Sarah D.
Horace
De Soto
Crain Boy
Illinois
Columbus
Bactus
Saint Joseph
Joubert
Botha
Kruger
Cronje
Chicago
Chief
Summit
Saint Louis
Coin
Cliff
Bay State
Philadelphia
Boston
Bonaparte
Hortense
Ophir
Portland
Mariposa
Glenbrook
Pocahontas



PLAN OF THE UNDERGROUND WORKINGS OF THE RAWLEY AND THE ANTORO MINES.