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Mines and ore deposits from Red Mountain Pass to Ouray, Ouray County, Colorado

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switch from wall to wall and center of the dike, make the Montana-Argentine very susceptible to dilution. As the pay streak switches from one position to another the stope will undercut the intervening blocky ground. Pillaring is commonly required, first, to prevent excessive dilution, second, to prevent large slabs from breaking away and blocking the stope draw, and third, as a safety measure for men working in the stopes.

In some areas, the vein and dike flatten together, and a set of fractures parallel to the steeper course persist upward. Heavy blocky ground invariably results.

A certain amount of dilution cannot be avoided because of slivers of dike rock 1-3 feet thick occurring between the vein wall and a gouge zone within the dike or along the dike wall. Such slivers cannot be held in mining, and sampling must include them or an erroneous impression of the grade of minable ore will result.

(3) As previously noted, two of the potential vein positions may simultaneously carry notable mineralization. Under these conditions it is necessary to decide whether the metal content of both is sufficient to carry the intervening dike waste, and if not, which position should be followed. In the majority of cases examined by the writer the width of dike waste (5 feet or more) was sufficient to preclude mining it and both vein positions. Of the two veins, one was generally narrow (2.5-4 feet) and of good grade, whereas the other would be wide (4-6 feet) and little better than minimum grade.

Choice of which vein position to follow when both cannot be mined depends on several factors: (1) the preferential position (if any) of the pay streak with respect to the dike in that area; (2) whether the pay streak consists chiefly of stage 2 quartz carrying abundant sulfides (most favorable), stage 1 heavy sulfide mineralization, or stage 2 quartz with little sulfide (least favorable); and (3) the fact that the vein position that will pinch out updip is more often associated with a very strong gouge slip.

MINES AND ORE DEPOSITS FROM RED MOUNTAIN PASS TO OURAY OURAY COUNTY, COLORADO

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INTRODUCTION

Some of the most unusual and interesting mineral deposits of the San Juan Mountains occur between Red Mountain Pass and Ouray. Although most of the mines of this area are now inactive, in the past they produced much silver and base-metal ore. The most important mines are on a series of breccia pipes along the eastern side of Red Mountain Canyon. The deposits and mines are described under three districts: Red Mountain, Ironton Flats, and Upper Uncompahgre.

RED MOUNTAIN DISTRICT

Chimney Ore Bodies

The Red Mountain ore deposits occur as chimneys and less important veins associated with a group of volcanic pipes that are confined mainly to a belt of altered and fractured rock in the zone of ring faults along the west and northwest side of the Silverton caldera. The belt of altered rock is 3,000-7,000 feet wide and about 7 miles long, extending from Anvil Mountain on the south to Red Mountain No. 1 on the north. The alteration extends vertically at least 5,000 feet, the rock showing partial to complete transformation to sericite, quartz, clay minerals, hydrated ferric oxide, alunite, diaspore, and pyrite.

Most of the deposits, and all the more productive ones, are in the northwest quarter of the alteration belt in a zone 15,000 feet long and about 3,000 feet wide, striking N. 30° E. This zone is bounded by Ironton Park on the north, Red Mountain Pass on the south, Red Mountain and North Mineral Creeks on the west (which also mark the edge of the alteration belt), and the lower slopes of Red Mountain No. 2 and No. 3 on the east. The zone is the center of a structural basin termed the Red Mountain sag by Burbank (1941). This basin is as much as 3 miles wide and in places 500 feet in depth.

The deposits occurred between elevations of 10,000-11,500 feet, a vertical range of 1,500 feet. However, the richer deposits at the north end showed a general accordance of elevation and the same vertical range.

The Red Mountain district was active between 1882 and 1900, when the Yankee Girl, Guston, National Belle,

Silver Bell, and Genessee mines were operative and the present ghost towns of Red Mountain and Ironton had populations of 400-500. Since 1900 there has been only minor mining or exploration. The deposits were notable for rich silver-lead and silver-copper ores, which ran 50 to several hundred onces silver and 15-40 percent lead or copper. However, the total tonnage produced was small and mining was expensive because of the generally small size, irregular shape, and erratic distribution of the ore bodies and the extremely corrosive acid mine waters. Estimates of total production from the district range from 10 to 20 million dollars with the lower value more nearly correct.

Volcanic Pipes

The volcanic pipes are nearly vertical cylindrical bodies with crescentic to elliptical cross section occupied by breccias and intrusive bodies of quartz latite porphyry and rhyolite. Age relations in the more complex pipes show the breccia formed first and was followed by porphyry intrusions. Brecciation continued concurrently with intrusion. The pipes range in shape from curved teardrops of the embryonic pipes to elliptical bodies, mostly compound, in the well-developed ones. The pipes are 300-2,000 feet long and 100-1,200 feet wide. Some of the breccia grades into relatively unbroken country rock but some of the smaller pipes possess nearly hairline bounderies. The better-defined pipes are encircled by an envelope of vertically sheeted rock, which forms a well-defined outside wall to the structure.

Burbank (1941, 1950) proposed the following sequence of pipe formation:

(1) Magmatic emanations, which passed up through favorably jointed fissured rock, caused chemical or volume changes along the axis of greatest concentration. The strength of the rock was impaired and local crackling and crumbling was induced.

(2) The zone of disintegration spread outward from the axis into the country rock along generally curved surfaces. The country rock was first irregularly veined and crackled, and ultimately was incorporated in the breccia as rock fragments with slightly rounded corners in a matrix of finely pulverized clastic material. The pipes assumed the curved teardrop shape, controlled by yielding of the rock along planes of maximum shearing stress.

(3) Textures suggestive of flow structure together with mineralogical changes indicate that the breccia in the final stages of formation was saturated with volcanic vapors and reacted by "plastic" flow rather than by fracturing. Passage of the breccia into a state of complete flow was gradual. The pipes now tended to assume a concentric form controlled by the concentric stresses around the plastic core. As the breccia mass spread into the surrounding rock the form was either that of a ring zone or a cylindrical core.

(4) Rhyolite and prophyry were intruded partly displacing the breccia core. The brecciated country rock was moved aside, sunk, or became assimilated either in rising fluids or in the molten intrusive rock. Further external fracturing ensued as a result of upthrusting by the intrusive bodies. Some pipes probably extended to the surface, resulting in eruptions of latite, rhyolite, and tuff. In some compound pipes the sequence was repeated along new axes after former axes were sealed.

Ore Bodies

Burbank (1941) distinguished between deposits within a volcanic pipe and those outside or at the margins of the pipes. The latter are localized by structures directly related to the pipe, such as cone-sheet fractures. Examples of the first type are the Yankee Girl, Guston, Robinson, and National Belle deposits, whereas the Hudson, St. Lawrence, Congress, and San Antonio deposits are of the latter type. The two types are related to the stage of pipe development. Those within the pipes are chiefly in incipient pipes not completely plugged with porphyry. Ore bodies lying within small- or moderate-sized pipes of this type include the most productive in the district, since they formed under conditions favoring concentration in feeding channels. Deposits exterior to the pipes are associated chiefly with pipes which are in an advanced stage of development and which are commonly "plugged" by porphyry bodies.

The ore bodies occurred as short veins and chimneys of nearly massive sulfide. The latter are most characteristic of the district, being the source of the richest ores and accounting for most of the production. The term "chimney" is somewhat misleading, as some of the ore bodies were lenticular, pod-shaped, or spindle-shaped, and were completely enclosed in country rock. Most had dimensions in the order of 150 x 30 x 15 feet, the longest dimension oriented vertically.

The ore bodies were formed by filling of irregular solution cavities and replacement of argillized and silicified rocks. The cavities resulted from hydrothermal leaching concomitant with alteration, the process further brecciating the country rock. Open cavities or "caves" were a prominent feature of the deposits, many of the cavities being lined with fine crystal specimens. Most ore bodies and the larger open cavities were related to some structural intersection, although in many cases the pervasive

alteration obliterated the control.

The common ore minerals included pyrite, enargite, chalcopyrite, tennantite, chalcocite, covellite, stromeyerite, bornite, galena, and sphalerite. Also present locally are colusite, cosalite, kobellite, polybasite, and unidentified sulfobismutites. Common gangue minerals are quartz, sericite, and the clay minerals: kaolinite, dickite, beidellite, and nacrite.

The chimneys showed prominent vertical zoning of ore minerals with changes occurring within a vertical distance of 1,000 feet or less. The deposits bottomed in pyrite which was capped successively by pyrite-chalcopyrite ore (containing most of the gold), ore composed of copper-silver minerals (enargite, tennantite, chalcocite, covellite, bornite and stromeyerite), and finally by galena, galena-silver, or galena-sphalerite ore. The galena-bearing ore in most places extended down for several hundred feet along one or more sides of the underlying copper-silver ore, and veinlets of galena locally cut the underlying zones. Microscopically the ores show evidence of comparatively rapid and overlapping deposition of the common minerals, the overall paragenetic sequence from older to younger being identical to the zonal sequence from the bottom upwards.

The ore bodies were enclosed in evelopes of silicified rock or jasperiod, broken by ramifying solution cavities, fissures, and open breccia masses which provided continuous passages. Sulfides, dickite, kaolinite, and alunite occurred filling or lining such cavities. The jasperoid graded outward into rock of the propylitic type, characterized by chlorite, carbonates, and locally pyrite and sericite. Limited observations suggest the beidellite-type clays formed mainly in intermediate positions between the silicified and propylized rock. The rock outside the siliceous envelope was much fissured but in general tighter, providing only sheeted zones, joints, and seams for penetration of fluids.

The size of the silicous envelopes declined in depth, changing from strong perforated cappings at the uppermost levels to tapering sheaths downward. In some deposits only barren silicified and channeled rock outcropped but ore was found at depth. The solution cavities, whether ore-bearing or not, also diminished in depth, tapering downward as roots. Pervasive alteration to quartz, coarse-bladed sericite, pyrite, and some carbonates was prominent at depth.

In some places the sulfides were attacked by acid solutions following the deposition of galena. In the National Belle mine large masses of the silicified and originally pyritized rock that formed the walls of caves in the upper 150 feet of the deposit were almost completely leached of sulfides, even the finest disseminated grains of pyrite and enargite, without leaving a limonitic residue.

Origin

Burbank (1941, p. 189-194) believed the deposits formed in a fumarolic or hot spring environment at depths of 2,000-3,000 feet. Deposition of the ores occurred near the end of the following sequence of structural events: (1) early faulting that outlined the downfaulted caldera block; (2) formation of the volcanic pipes; (3) development of the Red Mountain sag concurrent with general alteration of the rocks. The sag greatly influenced the fumarolic "plumbing system", serving as a trap for meteoric water and by its movement opening and closing mineralization inlets and outlets.

Burbank (1941, p. 194-197) postulated that the change from the quartz-sericite alteration and sulfide mineralization to the jasperoid-kaolin leaching-type alteration was related to the vaporization and partial recondensation of relatively acidic sulfate volatiles; these volatiles were derived from a high-pressure and high-temperature alkaline condensed fluid, which was fed from below through relatively tight fissures. The locus of vaporization thus represented an actual physical discontinuity. Concurrent with the alteration, the locus changed position along the channelway, depending on the relative volumes of juvenile fluid and meteoric water and on the "openness" of the channel way (which regulated the pressure controlling volatilization). The sericitic alteration permeated the ground below the channelways and resulted in tight pyritic veins or in disseminations and replacement deposits of sulfides related to pre-existing fissures. The acid sulfate alteration leached the rocks to form the caverns and chimney-like channels that were in most places the loci of greatest ore concentration. When these solutions became saturated with silica and alumina, the jasperoid and kaolin minerals of the siliceous chimney evelopes were deposited.

Although the position of the vaporization interface oscillated along the mineralization channelway, the interface moved generally upward due to the reduction of local porosity (and corresponding increase in pressure) resulting from silicification of the walls, the filling of the channel space with ore, and the slumping of the overlying weak rock masses. Wherever the pressures were un-

iformly maintained, vaporization and the concurrent leaching and silicification of the walls kept pace with the deposition of ore. Following the vanguard of the acid vapors, ore minerals were deposited in the leached cavities and chimneys, the deposition proceeding from lower levels upward in the general order of their precipitation in the paragenetic sequence. Where the channels became filled by earlier-stage minerals the later sulfides such as galena were deposited mainly as cappings, or, where further disturbances afforded access, as veins and replacement deposits in the walls of the chimneys.

Yankee Girl Mine

The Yankee Girl ore body was discovered in 1881 by John Robinson. The mine was developed rapidly and was the most productive in the district. Estimates of the value range from 3 million dollars (Ransome, 1901, p. 215) to 12 million dollars (W. Weston, private report). A value near the lower figure is probably correct.

The mine was developed to a depth of 1,050 feet. Ransome (1901) stated that a plan of levels showed an intricate maze of workings in which no linear system was discernible. Most of the workings were just west of the shaft, and in plan could be roughly enclosed in an irregular triangle. The mine workings are inaccessible; operations ceased in 1896. The mine produced some very rich ore. In 1883, 3,000 tons of ore averaged nearly $150 per ton in silver and lead. Several carloads carried 1,500-3,000 ounces of silver and 30-33 percent copper per ton. One 3-ton lot ran 5,301 ounces silver and 28.75 percent copper per ton.

The boundary of the Yankee Girl volcanic pipe is marked by 3 or 4 small bodies of porphyry, most of which lie against or not far from the envelope of the pipe. The shaft was sunk on one of the chimney deposits in the northeast corner of the pipe. The pipe is oval, being about 500 feet in north-south diameter and 400 feet east-west. The outcrop of the pipe so closely circumscribed the major part of the mine workings that Burbank believed there was little doubt that the pipe continues vertically to a depth of 1,000 feet with little change in diameter or shape.

The five chimneys in the Yankee Girl mine (the Yankee Girl, Orphan Boy, North, West, and South chimneys) are near the porphyry ore bodies, and the West chimney is near the border of the volcanic pipe. Only a few figures for the size of the ore bodies are known. The Yankee Girl chimney was circular in outline and 20-30 feet in diameter on the upper levels. On the 5th level the diameter decreased to 8-10 feet. On the 6th level (432 feet below the outcrop) the chimney was elliptical in plan, 32 feet long and 10 feet wide. A small neck of ore connected this chimney with the Orphan Girl, which lay 150 feet south. The West chimney on the 6th level was also elliptical, 8-10 feet long and 2-3 feet wide, oriented north-south. The dimensions listed for the Yankee Girl are probably typical, although ore bodies up to 140 feet long and 20 feet wide were encountered.

Emmons (1888) observed that many joint planes and cross fractures cut the ore bodies, which, where elliptical in plan, were oriented parallel to the strike of the main northwest system of fractures. Slickensided fractures marked many of the walls of the ore bodies.

The upper 75-125 feet of the chimneys carried pyritic galena ores, which in the Yankee Girl chimney ran 77 ounces silver and 36 percent lead per ton. Lead ores extended deeper in the Orphan Boy chimney than in the other other chimneys. Below the galena ore copper-silver ores appeared, consisting of stromeyerite, chalcocite, chalcopyrite, tennantite, and bornite with rare gangue quartz. Rich ores of this type in the Yankee Girl chimney carried 240 ounces silver and 29 percent copper per ton. Below a depth of 300-400 feet silver showed an overall, though irregular, decline, but bornite increased. Opinions differ on the mineralization at the bottom of the mine; one authority stated the ore was pyritic and of low-grade, while another noted that pyrite was rare and that rich copper (bornite-chalcocite) ore was abundant.

Guston-Robinson Mines

The Guston mine opened in 1882 but development was slow and large-scale activity did not begin until 1888. Operations ceased in 1897. The mine was a close second to the Yankee Girl as the district's leading producer. Ransome (1901, p. 220-221) estimated the production in excess of 2½ million dollars. The Guston mine was developed to a depth of 1,300 feet on 14 levels and the Robinson to a depth of about 700 feet. The Guston workings form an irregular maze concentrated in an area 550 feet long and 150 feet wide trending N. 20° E. Most of the mine is now inaccessible.

From 1888 to 1895 the Guston mine produced 69,127 tons of ore, the production varying from 315 tons (1888) to 14,833 tons (1895). Only in four years was production over 10,000 tons. The value of the ore per ton varied between $363 (1888) and $10.70 (1895), averaging $91.81. The best year was 1891 in which nearly 12,000 tons of ore averaging $70 was produced; some of the ore from the 6th level (depth of 378 feet) averaged 15,000 ounces sil-

ver and 3 ounces gold per ton, the richest recorded for the district. Mining costs averaged $23.43, varying between $53.50 (1888) and $9.60 (1894). The mine paid over a million dollars in dividends between 1888 and 1897 while operated by the New Guston Company, Ltd.

The Guston and Robinson ore bodies appear to be within a single pipe, which is about 1,200 feet long north to south. One highly altered body of porphyry is exposed along the northeast rim of the pipe. The southwest rim is marked by a curved zone of highly sheeted and sheared rock. Several large bodies of unshattered rock lie within the pipe envelope.

The ore bodies are roughly elliptical masses standing nearly vertical and consisting of almost solid ore with very little gangue. Some stopes were about 200 feet long and several hundred feet high. The ore width varied greatly in different bodies and in different parts of the same body, with 20-30-foot widths common. The stopes showed the greatest aggregate length (about 600 feet) on the 5th level and shortened rapidly below.

The ore bodies were associated with an "ore break", a zone as much as 60 feet wide of altered, disturbed, and more or less broken country rock that is intersected by slip planes and contains much kaolin as well as soft attrition material. The "ore break" strikes N. 10°-20° E., connecting the sides of the volcanic pipe. Although related to the ore break, the ore bodies were irregularly placed with respect to it. Careful prospecting by diamond drilling was required to find the ore. Most elliptical ore bodies paralleled the "ore break", but individual ones showed considerable strike variations. The "ore break" dipped steeply east between the surface and the 7th level (364 feet depth). At this level it was offset 30-50 feet west by a slip dipping 45° west. From the offset to the 10th level the "ore break" dipped west and carried little ore. On the 10th level the dip reverted to the east and the ore was better than any encountered below the 7th level, although of limited quantity.

The ore showed distinct zoning. Galena ore carrying 50-60 percent lead and 30-40 ounces silver extended from the surface to a depth of 288 feet, although in greatly diminished quantities below 130 feet. Below were stromeyerite-chalcopyrite-pyrite ores carrying 0.1-3 ounces gold, 25-700 ounces silver, and 9-15 percent copper. The lower-grade ore in the deeper workings was pyrite carrying less than 20 ounces of silver, less than an ounce of gold, and 3-5 percent copper per ton. The best ore encountered on the 10th level and below consisted of bornite, chalcopyrite, and pyrite assaying 60-175 ounces silver, 0.2-1.0 ounces gold, and 18-25 percent copper. High silver values were associated with bornite ores, and high gold with dominantly chalcopyrite ores, while pyrite ores contained only moderate silver values. Small quantities of free gold associated with barite were encountered below the 9th level.

Ransome (1901, p. 226) concluded that there was first an increase in the value of the ores down to the 6th or 7th level, and then a sudden falling off in value at the slip plane below the 7th level. Below this the ore diminished in richness down to the bottom of the mine. The characteristic ore minerals, in the order of the increasing depth at which they prevailed, were galena, stromeyerite, (pyrite?), bornite, chalcopyrite, and pyrite. This succession is true only in general terms. Sudden and perplexing changes in the value and mineralogical composition of the ore occurred within the individual ore bodies at all levels, and the various minerals overlapped in most complex fashion, although the bornite apparently had a definite upper limit and the stromeyerite a definite lower limit. Of all the ore minerals pyrite appears to have had the greatest vertical range and undoubtedly formed an increasing proportion of the ore with depth.

Little is known of ore localization in the Robinson mine. The mine produced some good ore but reportedly bottomed in pyrite at a depth of 600-700 feet.

National Belle Mine

The National Belle mine was worked from 1883 until 1897. Production is unknown, but probably was between 1 and 2 million dollars (Ransome, 1901, p. 231-236). The mine was developed to a depth of 450 feet. Old maps show the workings were concentrated in two areas along a line striking N. 35° E. The north area, 200 feet north of the shaft, was more thoroughly developed. Four levels were mined, with the workings concentrated in a circular area 150 feet in diameter. The south area, 200 feet west of the shaft, was worked extensively on only levels, with the workings concentrated in an area 150 feet long and 100 feet wide. Most of the mine is now inaccessible.

The National Belle volcanic pipe is a small composite pipe consisting of the main mineralized pipe about 400 feet in major diameter, and a smaller porphyry-bearing pipe on the northeast about 300 feet in major diameter. All the main workings lie beneath the larger pipe, which has a rim zone of highly silicified and leached rock. The knob of altered rock stands about 200 feet above the sur-

rounding topography. The outcrop of the mineralized chimney is composed of three main parts. The core, exposed on the top of the knob, is composed of moderately silicified and kaolinized rock. Surrounding this core is a crude angular ring of strongly silicified rock that forms the steep sides of the knob. The sides contain many natural caves in which oxide ores were found. The outermost zone consists of strongly sheeted pyritized, sericitized, and kaolinized rock. This unleached envelope zone contrasts with the two inner zones, whose outcrops are almost completely leached of disseminated sulfides. The strongest zone of fissuring and leaching extends along the east wall of the pipe and corresponds with the trend and position of the underground workings. Surface outcrops also suggest minor chimneys of ore at the northwest edge of the pipe and along the north rim. The two inner zones contain bodies of breccia, some of which belong to the volcanic stage and some probably to later stages of slumping resulting from volume losses during alteration.

The ore was found in caves, which were distributed irregularly along fissures in the jasperoid of the chimney's central ring. The caves coalesced and decreased in size with depth. Oxide lead ores were mined in the upper levels and accounted for most of the early production. The oxide ores were porous, spongy masses of quartz crystals, cerussite with galena cores, clay minerals (notably abundant pure kaolin), alunite, barite, and malachite around remnants of enargite. The entire mass was encrusted or stained by limonite. The ores occurred attached to the walls of caves, as unbroken detached masses, and as beds of clay and sand filling caves. The oxide ores ran 5-7 ounces of silver and 15-60 percent of lead per ton. One oxide ore body had dimensions of 40 x 20 x 10 feet high.

Below the oxide ore, sulfide ore (pyrite masses containing enargite, chalcopyrite, tetrahedrite, and galena) was encountered, the pyrite locally being more extensive than the ore. Enargite was abundant, in places lining caves with radiating prismatic crystals overgrown by quartz. The sulfide ore occurred in irregular masses 30-50 feet long and 1-4 feet wide. The so-called North ore body mentioned below was notably larger than the average

Galena occurred as streaks in the pyrite-copper minerals, and carried up to 44 ounces silver and 60 percent lead. Galena was negligible below the 2nd level. The best sulfide copper ore ran 0.1 ounce gold (but usually much less), 3 ounces silver, and 40 percent copper. The principal ore metals, in order, were copper, silver, lead, and gold.

The ore bottomed at shallow depth. The North ore body on the 2nd level was 75 feet long, 60 feet wide, and assayed 7-25 ounces silver and 7-20 percent copper. On the 3rd level the ore was 31 feet long, 24 feet wide, and assayed 4-7 ounces silver, 0.04 ounces gold, and 4-6 percent copper. The ore body was absent on the 4th level, where very little ore was encountered anywhere; mineralization consited chiefly of small masses of crumbly pyrite assaying 0.01 ounce gold, 5 ounces silver, and 3-5 percent copper.

Burbank (1941) believed the oxide ore may not be the product of surface meteoric oxidation as was formerly supposed. He suggested hydrothermal leaching and oxidation by sulfate solutions, with minor meteoric activity accounting for the transformation of sulfate to carbonate. The thorough leaching of finely disseminated sulfides without a resulting limonite boxwork, and the shallow and quantitatively insignificant oxidation elsewhere in the area, are cited as evidence.

Genessee-Vanderbilt Mine

Work began in the Genessee mine in 1882 but development was slow as most of the work was from shallow shafts. About 1889 the Genessee and Vanderbilt mines were combined, with the period of greatest development from 1891-1896. Although the mine produced some good ore it was never very profitable. Production from 1891 through 1896 was 12,622 tons of ore containing 2,884 ounces of gold, 436,675 ounces of silver, 702,183 pounds of lead, and 30,520 pounds of copper. The gross value of the production was probably slightly under 1 million dollars.

The mine was developed from a tunnel running southeast 820 feet; at the end a shaft was sunk 700 feet. The tunnel was later extended about 3,700 feet southeast beyond the shaft. Five levels were developed from the shaft; workings were concentrated in a circular area 100 feet in diameter located 100 feet northeast of the shaft. A crosscut from the 300-level was extended in an arcuate course about 2,000 feet east of the shaft, and was driven through the Champion Gulch pipe to explore the east rim of that pipe by several short drifts.

The Genessee-Vanderbilt volcanic pipe, which lies close to the southwest rim of the much larger Champion Gulch pipe, may have formed after plugging of the larger pipe by intrusion of rhyolite. The outcrop of this pipe is a half-moon-shaped ledge of silicified breccia, and no porphyry is exposed. Judging from mine maps the north-south diameter of the pipe is about 600 feet.

Reputedly, there were four ore chimneys at the surface (Ransome, 1901, p. 228), but only one was followed to the 700-level. One chimney examined by Ransome near the surface was elliptical, the longest axis vertical, and the medial axis trending north-south.

No high-grade ore was found and the best ore occurred at a depth of 250 feet. The tenor fell off gradually below 300 feet and rapidly below 500 feet. On the 700-level mineralization was only low-grade pyrite. Assays showed values for the upper workings of 0.2-0.4 ounce gold, 30-45 ounces silver and 2-3 percent lead, and values for the 500-level and below of 0.07 ounce gold, 18 ounces silver, and 0.06 percent lead.

The mineralogy is not well known. Galena reportedly was abundant near the surface and occurred in considerable quantities to the bottom of the mine. The assays, however, indicate that bodies of predominant galena must have been few and of small size, at least in the lower levels worked after 1891. Sphalerite was locally abundant in the uppermost workings. Cosalite reportedly was an important ore mineral, and bornite and proustite were present.

In the late 1940's the mine was reopened by the American Smelting and Refining Co. and intensively explored, especially in those areas of intense silicification and alteration on Red Mountain No. 3 described by Burbank (1941). The tunnel was rehabilitated and three headings were driven from near the face of the tunnel. In 1947 one heading had been driven about 1,500 feet southwestward, a second driven slightly west of south about 1,000 feet, and a third driven southeastward about 300 feet. Diamond drilling was done from the crosscuts. Some small bodies of pyrite-enargite-chalcopyrite ore were discovered, but most were low grade. Perhaps the best of these, encountered. 700 feet below the surface, was a pyrite-enargite chimney 30 x 20 feet in cross-section assaying 170 ounces silver and 36 percent copper.

Silver Bell Mine

The Silver Bell mine operated from the early 1880's until 1894. Between 1887 and 1889 the mine produced ore valued at $178,000, largely of silver. Total production is unknown, but as the mine was among the district's leading producers, 1 million dollars is a fair estimate.

The mine was worked from a shaft 706 feet deep from which 10 levels were driven (Ransome, 1901, p. 238). These workings are now inaccessible. The mine was in a group of chimney ore bodies, circular to elliptical in plan. The elliptical bodies were oriented north-south. The largest ore body, which extended from the surface to the 6th level, a depth of 250 feet, was about 50 feet wide and 5-10 feet thick. Between the 6th and 7th levels a circular chimney about 50 feet high and 30 feet in diameter was stoped. Between the 7th and 8th levels (75 feet) two ore bodies of irregular shape were mined, about 25 and 100 feet respectively in stope length, and 5-20 feet thick. Between the 8th and 9th levels (75 feet) three ore bodies were mined, only one of which was stoped to the 8th level. This was a circular chimney 5-10 feet in diameter. The other two bodies were mined for lengths of 90 and 25 feet and heights of 25 and 10 feet respectively.

Not much is known of the grade and mineralogy of the ore. Reputedly large amounts of ore carrying 500-1,000 ounces silver per ton were produced in 1888. Rich ore from upper levels changed downward to large bodies of low-grade ore consisting chiefly of pyrite and carrying less than 20 ounces of silver. Attempts to work this material after the fall in silver prices were not successful. Argentiferous lead sulfobismuthites apparently were important constituents of the ore and kobellite also was identified.

Congress Mine

The Congress mine was worked intermittently between 1881 and 1900. From 1912 to 1918, 7,184 tons of ore were shipped to the Durango smelter; this ore and averaged 0.313 ounce gold, 5.75 ounces silver, 8.58 percent copper, 4.44 percent lead, and 5.75 percent zinc. Total production is unknown but probably was nearly one-half million dollars.

The mine was worked from a shaft 350 feet deep at the end of an adit tunnel (Ransome, 1901, p. 238). Total extent of the workings is unknown as they are now inaccessible. The ore chimney is reportedly at the intersection of a north-south fracture with the envelope of the Congress volcanic pipe. The ore was chiefly enargite and pyrite carrying gold. Galena occurred to considerable depth on the peripheries of the pyrite-enargite bodies. The enargite seen near the surface had been partly brecciated and recemented by a compact but soft aggregate, apparently largely kaolin.

St. Paul Mine

The St. Paul mine was a small producer that was worked intermittently from the 1880's into the 1900's. The shaft was 200 feet deep but the extent of level workings is unknown. The St. Paul ore chimney is south of the

large Koehler compound volcanic pipe. The chimney is at the intersection of north and northeast fissures with the exterior cone fractures of the volcanic pipe. A small body of porphyry lies just south of the main chimney. The ore was low grade and consisted chiefly of enargite with some galena, forming a fine-grained aggregate (Ransome, 1901, p. 238). It occurred as irregular replacements in altered country rock with no definite boundary. The altered country rock contained considerable disseminated pyrite and small knots and veinlets of kaolin. Although the kaolin seams were very irregular in strike and continuity, prospecting consisted largely of following these seams – a technique applied successfully in some of the larger mines in the district.

San Antonio (Carbon Lake) Mine

The San Antonio mine operated intermittently between 1878 and 1950. Prior to 1893 the mine production was valued chiefly for silver. From 1907 to 1910, 7,777 tons of ore shipped to Durango averaged 0.1 ounce gold, 7.73 ounces silver, 10.54 percent copper, 6.19 percent lead, and 2.95 percent zinc. Nineteen carloads shipped during 1926, 1927, and 1937 averaged 0.125 ounce gold, 8.45 ounces silver, 7.25 percent copper, 11.25 percent lead, and 6.8 percent zinc. Total production is unknown, but probably is between one-fourth to one-half million dollars.

The upper half of the mine was developed from the Salem and Carbon Lake shafts, 50 and 200 feet deep respectively. The lower half of the mine was developed from the Carbon Lake lateral (500-foot-level) off the 2000-foot-long Koehler tunnel. The San Antonio ore deposits are east of the Koehler compound volcanic pipe. The ore chimneys were localized at the intersection of north-south and east-west fractures, the former belonging to the sheeted envelope of the pipe.

The ore bodies were confined to a circular cylinder 90 feet in diameter, and 500 feet long, plunging about 70° north. Ten ore bodies were mined. Five were pencil-shaped, having a length of 60-150 feet (oriented vertically) and a circular or elliptical cross-section with dimensions of 10-30 feet. The other five bodies were cylindrical, having a length (oriented vertically) of 20-70 feet and an elliptical cross-section of 10 x 20 to 20 x 60 feet. The ore consisted of enargite and pyrite with lesser amounts of galena and sphalerite. Appreciable amounts of kaolin filled the interstices. Fringes of the ore bodies were heavily mineralized with pyrite.

Joker Tunnel

The Joker tunnel (now caved) was driven from near the head of Ironton Park to the main shaft of the Genessee-Vanderbilt mine, a distance of 4,800 feet. The tunnel runs slightly west of south. Laterals west and east off the tunnel connect with the Yankee Girl and Guston mines respectively. The three mines were intersected at depths of 400 feet (Guston), 500 feet (Yankee Girl), and 600 feet (Genessee) below their respective main shaft collars.

Although the tunnel is not mentioned by Ransome (1901), residents of the area state it was started in the late 1880's. There apparently was little production through the tunnel, as the Guston and Yankee Girl (the main producers) were probably reached after production had declined notably; production, if any, was coming from levels below the tunnel intersection. Last operations were in the late 1930's when the the tunnel was reopened to the Guston mine and several unpulled stopes of pyritic gold ore were removed.

Saratoga, Mono-Baltic, Maud S., and Brooklyn Mines

These mines are unique, for, although associated with a volcanic pipe, the deposits consist of veins and associated replacements in limestone rather than in chimneys.

The Saratoga deposit was discovered in 1883, and the others were probably found at about the same time. The most productive years were from 1886 to 1890. Ransome (1901, p. 241) credited the Saratoga mine with a production of $125,000 up to 1900. This came from three classes of ore: (1) siliceous gold-silver ores averaging 59.4 ounces silver and 0.21 ounce gold, but with a few ton lots running as high as 3 ounces gold or 300 ounces silver; (2) lead-silver ores, running 0.10 ounce gold, 25-50 ounces silver, and 25 percent lead; (3) pyritic silver-copper ores, running 0.05-0.10 ounce gold, 20-25 ounces silver, and 13 percent copper. Most of the production was from silver-lead ores.

The Saratoga was developed from a 1,000-foot tunnel running southeast. A southwest branch off the tunnel is about 300 feet long and occurs about 250 feet from the portal. At least one level, containing several hundred feet of workings, existed above the tunnel, and there was a lower level of unknown length.

In 1907 the properties were rehabilitated and a pyritic smelter was erected in Ironton Park to treat the pyritic ores in the mines. The results of this experiment are unknown but apparently were not too successful.

The Mono-Baltic mine was developed from an east-trending tunnel 700 feet long. A shaft from the tunnel connected with the surface and four intermediate levels contained several hundred feet of workings. The Maud S. tunnel, at the same elevation as the Mono-Baltic, trended north. Levels were driven above and below the tunnel. The Brooklyn tunnel prospected ground north of the Mono-Baltic vein. Workings off the tunnel aggregated well over 1,000 feet. The majority of these workings are now inaccessible.

The mines are in an uplifted circular block 1,000 feet in diameter, the Saratoga volcanic pipe of Burbank (1941). The area is on the east limb of a north-south anticline, the crest of which lies along Ironton Park. The stratigraphic sequence consists of quartzite of the Precambrian Uncompahgre formation overlain unconformably by 50-100 feet of the Devonian-Mississippian Ouray limestone, which which dips about 20° southeast. Uncomformably overlying the Ouray limestone are scattered remnants of Telluride conglomerate (Oligocene?). The San Juan tuff (Miocene?) overlies the conglomerate or the Ouray limestone.

In the Saratoga mine, the ore occurred as replacement lenses of argentiferous cerrusite, galena, and pyrite localized at the limestone-tuff or limestone-conglomerate contact , with the replacement extending in some cases through the entire limestone layer. The rich silver-lead ores, which accounted for the bulk of production, occurred at the top of the lenses and ranged in thickness from a few inches to 2-3 feet. Below was granular pyrite containing silver-copper ores. These ore bodies were found along a line bearing about N. 30° E., suggesting control by fissures, although no fissures were seen by Ransome. Where the main Saratoga tunnel passed from limestone into tuff, a quartz-pyrite vein 2-3 feet wide, striking N. 30° E. and dipping steeply southeast, was encountered. Beyond this vein is a zone 50 feet wide of shattered quartz, limestone, and pyrite – apparently the east border of the Saratoga pipe.

The Mono-Baltic and Maud S. deposits were of veins filling normal faults and adjacent replacement lenses in the limestone at the same stratigraphic horizon as those in the Saratoga mine. The faults strike N. 35°-45° E., dip 75°-85° SE, have displacements of about 100 feet, and bring tuff on the southeast against limestone on the northwest. The ore, massive pyrite and chalcopyrite, is largely confined to the fault zones with the width of mineralization decreasing where both walls are tuff and increasing where one or both walls are limestone. Replacements are more sparsely scattered in the Maud S. deposit. The Brooklyn tunnel explored the limestone block between the Mono-Baltic and Maud S. mines. Two large and several small replacement masses of crumbly pyrite were found.

Fissure Veins

Although the veins described below are geographically in the Red Mountain district, structurally and mineralogically, they are typical of the Telluride district to the west.

Barstow Mine

The Barstow mine developed a series of small gold ore shoots near the south end of the Barstow-St. Paul vein. The mine was operated by a company from 1895 to 1913, after which leasers operated briefly for various periods. The mine has produced about $700,000, chiefly of gold and silver, and 17,000 tons of fluorspar running 85-90 percent CaF_2.

The Barstow mine contains 11,600 feet of drifts, now all inaccessible. The main levels, each 3,700 feet long, portaled at the mine at altitudes of 11,206 and 11,036 feet. A level 1,600 feet long and 340 feet above the upper tunnel was driven over the central ore shoots. The remainder of the level work was in short drifts off raises above the upper level and winzes below the lower level. The mine was connected to the Treasury tunnel by a crosscut from the Handicap vein drift and a raise to the old workings.

The Barstow-St. Paul vein strikes about N. 40° W. and dips 70° SW. In the Barstow area the vein fault shows a net slip of 450 feet along a line pitching 45° SE in the plane of the vein. The vein was 3-5 feet wide and consisted of coarse white quartz containing "slivers" of wallrock and erratically distributed pockets of base-metal sulfides. Old reports stated the most consistent features of the vein were: (1) a gouge streak on the hanging wall, and (2) a galena-sphalerite streak 1-8 inches wide on the footwall. Gold was not associated with any particular sulfides, occurring either with them or with white quartz. Highest gold values were associated with dark colored quartz containing minute sulfide grains. The strong outcrop of the vein is marked by pyritized and sheared country rock containing quartz-sulfide stringers.

The mine is on the north margin of the Silverton caldera ring-fault belt. One of the ring faults, the Lake fault, drops the Picayune-San Juan contact 150 feet on the south. Several other small veins intersect the Barstow in the mine area. One of these, the so-called fluorite

vein, was the source of the fluorspar production.

The vein forms a cymoid loop in the center of the mine. The loop widens and increases in length with increasing depth. The two largest ore shoots, the north-central and south-central, were at opposite ends of the loop on the hanging wall and footwall branches respectively. The four ore shoots, from south to north, were about 100, 200, and 500 feet apart. The respective dimensions in feet (strike length and dip length) are: 450 x 250; 800 x 400; 450 x 450 and 200 x 150. The shoots all terminated upward at about the same horizon, which for the three northern shoots corresponded to the San Juan-Picayune contact on the hanging wall of the Barstow vein. However, the south shoot is on the downthrown side of the Lake fault and persisted 150 feet above the contact.

Ore control appears related to: (1) to the downdip cymoid loop on the Barstow vein; (2) the intersection of minor cross veins and fractures; and (3) possibly the contact between the San Juan tuff and the Picayune volcanic group.

Mountain King Mine

The Mountain King mine developed a vein striking N. 65° W.; the vein is traceable on the surface for 6,000 feet, passing below Ironton Park on the east and horsetailing on the west. The vein lies in echelon 250 feet north of the southeast end of the Hidden Treasure vein, and some of the horsetail strands link the two veins. The vein is in a highly faulted part of the ring-fault belt, and the workings pass laterally from Picayune volcanics on the east into San Juan tuff on the west.

The main tunnel is several thousand feet long. Crosscuts and short sublevels were driven from the tunnel. The workings are inaccessible. Mineralization consisted of scattered lenses and pods of galena and sphalerite carrying good silver and fair gold values. The walls of the vein are heavily altered, therefore the mine workings were extremely difficult to maintain. Descriptions by the most recent operators (late 1940's) suggested some mineralization extended away from the main vein along the ring faults.

IRONTON FLAT DISTRICT

This district includes two of a group of small veins lying on the margins of Ironton Flat. Geologically they occupy the fringe area between the Red Mountain district on the south, the Telluride district on the west, and the Uncompahgre district on the north.

Beaver And Belfast Mine

The Beaver and Belfast mine developed a north-south vein that crops out in the San Juan tuff. The vein is in the Silverton caldera ring-fault belt. The mine contained several thousand feet of drifts driven from several tunnels. The vein was 1-4 feet wide and consisted of quartz, galena, sphalerite, pyrite, chalcopyrite, and rhodonite. The walls were intensely altered. The ore shoots rake (pitch) 45°. Concentrates and hand-sorted ore produced in 1899 averaged about 0.04 ounce gold, 7 ounces silver, 53 percent lead, and 12 percent zinc. Eight hundred tons of sorted ore shipped in the 1940's ran 0.004 ounce gold, 4 ounces silver, 8 percent lead, 2 percent copper, and 9.5 percent zinc.

Ida L. (Larson Bros.) Mine

The Ida L. mine developed two short veins that strike west within the San Juan tuff. The mine consists of a single level reached by a crosscut tunnel 180 feet long. A second crosscut connects the two veins, which have been drifted for several hundred feet. A few short raises and one winze were sunk on the southernmost vein. The north vein is nearly vertical, but the south vein dips 65° SE. The vein averages about 5 feet wide. Vein-filling is principally quartz with local galena, sphalerite, and some chalcopyrite and pyrite. Total production is unknown but small. Nine tons shipped in 1946-47 averaged 0.025 ounce gold, 7.6 ounces silver, 12.05 percent lead, and 7.8 percent zinc.

UPPER UNCOMPAHGRE DISTRICT

The brief descriptions of mines included under this heading are for the canyon region of Red Mountain Creek below Ironton Flats and for the part of Uncompahgre Canyon from the junction with Red Mountain Creek to Ouray. The relief and rugged terrain are greater than any along the entire field trip route. The rocks of the lower part of the canyon, generally below about 10,000 feet altitude, consist of folded and faulted slate, quartzite, phyllite, and conglomerate of the Uncompahgre formation. In the northern part of the canyon a thin wedge of sandstone, shale, and limestone of the Elbert, Ouray, and Leadville formations crops out along a narrow bench above the Precambrian rocks. Elsewhere the Precambrian is overlain by Telluride conglomerate, San Juan tuff-breccia, and flows, breccia, and tuff of the Silverton volcanic group.

Fissure veins transect all the outcrops and a few veins may be followed from the Precambrian upward through the full thickness of the San Juan tuff, a vertical outcrop range of 2,000-3,000 feet. The fissure veins of this area

however, are short when compared to those of the Mineral Point district or those of the Sneffels district. Ore has been mined from deposits in all the exposed rocks which range from Precambrian to late Tertiary in age. The mines are small, and operations and output of ore have been sporadic. Only a few of the principal mines are described; a fuller account has been given by Kelley (1946, p. 355-372).

Guadaloupe Mine

The Guadaloupe mine is on the north side of Hendrick Gulch which enters Red Mountain Creek at the lower end of Ironton Flats. The deposit was discovered and worked chiefly prior to 1900. No output record is known for the early period but it probably was not large. Since then only about 406 tons, yielding a total of 9.54 ounces of gold, 17,761 ounces of silver, and 158,528 pounds of copper, had been produced through 1946. The vein strikes N. 5°-10° W. and dips 65°-80° E.; it was entered through the York tunnel (altitude 10,988 feet) and the Lucky Twenty tunnel (altitude 10,315 feet). The vein is in the eastern arm of a semicircular latite dike.

Dunmore Mine

The Dunmore mine is at an altitude of about 9,100 feet along the west side of Red Mountain Creek about one-fourth mile above its junction with Uncompahgre Creek.

The Dunmore vein or lode is the most varied and complex of any in the entire area. It extends from Precambrian quartzite upward into breccias of the San Juan tuff. The controlling fault fissure offsets the beds of the Uncompahgre formation by at least 2,800 feet in pre-San Juan time, and subsequent displacement has offset the San Juan beds 80 feet vertically. In the quartzites of the Uncompahgre formation the lode is 100 feet wide throughout the 800 feet of its exposed length. In the overlying breccias of the San Juan tuff, the lode narrowed to an average of only a few feet. The north half of the lode in the Precambrian rocks consists of upturned mineralized slates that had been sharply dragged past truncated quartzites of the north wall in pre-San Juan time. The south half of the lode consists generally of siliceous vein matter that is largely barren. The south wall lies along the principal fissure of the fault zone and most of the displacements have occurred on it, including considerable postmineral slipping which resulted in mashing and brecciation of much ore. In addition to the lode there are two chimneys of ore-bearing breccia. Between the lower and upper portals is a breccia chimney and a tungsten ore shoot which is 8-20 feet wide and 40-50 feet long. The ore is principally in a silicified area immediately north of the south wall. This chimney consists of a breccia of fine-grained quartz, sericite, and kaolin, partly filled and cemented with huebnerite, coarse-grained quartz, and lesser quantities of sphalerite, galena, hematite, and barite.

The other chimney or pipe in the lode is west of the upper portal and in some places shows more features of a breccia pipe than in others. Fine-grained siliceous material, such as occurs in the tungsten chimney and in the generally silicified areas of the lode, is widely replaced by specular hematite. All stages of this replacement are shown, but in most places the replacement is complete enough to constitute a potential source of iron ore. Within the hematite chimney and near its western margin is a copper-ore chimney, in which chalcopyrite and aikinite (Cu_2S, 2 PbS, Bi_2S_3) are the principal ore minerals superimposed upon the siliceous hematitic material. The gangue also contains rhodochrosite, chlorite, and barite. Pebble and breccia dikes of quartzite and slate are injected into the walls; these contain pyrite, quartz, and kaolin, but no ore minerals.

The tungsten (huebnerite) deposits, probably the latest mineralization products, are also sparingly present in the part of the vein above the base of the San Juan tuff. The prominent yellow knob that stands above the chalcopyrite chimney is largely barren mineral matter and intensely altered rock, and the widening of the lode in the base of the San Juan appears to be due to the numerous smaller veins formed in the prominent N. 10° W. fissures in the San Juan tuff.

Although the Dunmore lode appears to be of late Tertiary age there is no direct evidence that some of the mineralization did not take place during the early Tertiary period so prominently represented at Ouray; in fact, the greater size of the lode in the Precambrian rocks is suggestive of this earlier period. The fissure is pre-Tertiary in age in part, and probably was one – if not the most important – feeder channel for many veins in the volcanic rocks of the Upper Uncompahgre district.

Silver Link Mine

The Silver Link mine is above the bold quartzite cliffs that rise above the Mineral Point road about 2,100 feet east-southeast of the State bridge on U. S. Highway 550. The mine portal is at an altitude of 10,500 feet in the quartzites of the Uncompahgre formation and a few feet below the base of the San Juan tuff. The principal adit is a crosscut 1,500 feet long. The upper or early workings on the vein, known as the Seaburg drift, are more

than 800 feet long. The strike of the vein is N. 5° - 10° W.

Ransome (1901, p. 198) described the deposit as follows: "The lode is a sheeted zone 20 feet or more in width. The ore is chiefly bornite and tetrahedrite, carrying silver and chalcopyrite, and occurs in bunches along some one of the fissures. It is found in quartz, which is largely silicified San Juan breccia. It contains from 20-30 percent copper and sometimes as much as 300 ounces of silver per ton. The best ore is said to occur in solid quartz. There has been considerable post-mineral movement along the lode, resulting in soft gouge, and where the disturbance is pronounced it is regarded as unfavorable for ore. The ore usually occurs near the west (called the foot) wall, but it is far from continuous. The country rock on both sides of the lode is traversed by numerous parallel fissures, along which there has frequently been some late movement, as attested by the presence of wet clay gouge." Over 2,200 feet of drifting has been done along the vein. Most of the veins bottom at the Precambrian surface. The Silver Link mine is one of the oldest in the district, the tunnel work and much of the drifting having been done in the early eighties.

According to the Mint reports, ore worth about $50,000 was shipped from the Silver Link mine from 1888 to 1891. The mine was idle from 1893 to 1899 and then was reopened and operated for several years. In 1902 shipments of 70 tons of ore grossed 12.0 ounces of gold, 1,685 ounces of silver, and about 44,084 pounds of copper.

Sutton Mine

The Sutton mine is on the west side of Uncompahgre Canyon at an altitude of 10,595 feet. The mine is reached by road and trail from the old Mineral Farm mine south of Ouray. The mine workings consist of four levels, with the principal workings along the No. 4 level, where a 925-foot crosscut known as the Barber tunnel cuts the vein. An aerial tramway 2,700 feet long leads from the Barber tunnel to a 100-ton mill located at Bear Creek Falls.

The Sutton vein dips roughly 70° SE., strikes about N. 40° E. on the No. 1 level, and about N. 30° E. on the No. 4 level. In the few places where the vein was observed it is highly siliceous with a low sulfide content that appeared to be principally pyrite. Mill returns, however, indicate that the ore contained some galena and copper sulfide. The Sutton vein bottoms at the Precambrian quartzite, at an altitude of about 9,700 feet. Near the base of the San Juan tuff about 200 feet of drifts has been driven along the vein and its short branches. The vein here strikes N. 25° - 35° E., dips 75° S., and is a few inches to four feet wide.

In 1917 eight tons of ore shipped to the smelter grossed 0.42 ounce of gold, 404 ounces of silver, and 352 pounds of copper. In 1925, 36 tons of lead ore were milled and yielded 7.46 ounces of gold and 626 ounces of silver.

MINERALOGICAL NOTES ON THE SILVERTON QUADRANGLE, COLORADO

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INTRODUCTION

During the long history of mining in the districts of the Silverton quadrangle, considerable amounts of gold, silver, copper, lead, and zinc have been produced. The ores mined were primarily composed of the more common minerals of these metals. In some deposits, however, especially some of the silver-rich ones, a few rather exceptional, even unique, mineral species have been found. Locally some of these are important ore minerals, as well as potential sources of metals not previously sought, such as bismuth and tungsten. Several of these minerals were first described from this area, and at least one has never been reported from any other locality. This paper provides a brief description of the minerals which are characteristic of the ores of the Silverton quadrangle.

The deposits are generally grouped into three structural and genetic classes as follows: (1) fissure and cavity fillings, (2) breccia-chimneys, and (3) replacement deposits. Although largely distinct, the classes may be mixed within a single deposit. The three classes are mineralogically similar, varying more in texture and bulk composition than in mineral species present. On the other hand, the mineralogical composition may vary considerably from one deposit to another and from one part of the quadrangle to another. Gold mineralization, and to a lesser extent silver, tends to be separated from the base-metal ores, especially lead and zinc, whereas copper ores frequently contain considerable amounts of silver.

Although Ransome (1901) has suggested that the minerals in some of the richer ores were supergene, it has