The Idarado Mine

James R. Hillebrand

1968, pp. 130-140. https://doi.org/10.56577/FFC-19.130

in:

San Juan, San Miguel, La Plata Region (New Mexico and Colorado), Shomaker, J. W.; [ed.], New Mexico Geological Society 19th Annual Fall Field Conference Guidebook, 212 p. https://doi.org/10.56577/FFC-19

This page is intentionally left blank to maintain order of facing pages.

THE IDARADO MINE

By

JAMES R. HILLEBRAND

Idarado Mining Company

INTRODUCTION

The Idarado mine lies beneath the high ridge between Red Mountain Valley and Telluride, and is in both San Miguel and Ouray Counties, Colorado. The mine contains more than 80 miles of interconnected drifts or crosscuts on or connecting the Ajax-Smuggler, Tomboy, Liberty Bell, Alamo, Virginius, Pandora, Flat, Japan, Flora, Cross, Ansborough, Handicap, Barstow, Montana-Argentine, and Black Bear veins. Approximately 100,000 feet of drifts and 37,000 feet of crosscuts are accessible, and are mostly on the Montana-Argentine and Black Bear veins and Ajax section of the Ajax-Smuggler vein. Present operations are confined to the Black Bear and Montana-Argentine veins; therefore the description is limited to them.

Access to the mine (Fig. 1) is through either the Treasury tunnel, whose portal is below Red Mountain Pass on U.S. Highway 550 at an altitude of 10,600 feet, or the Mill Level tunnel entrance 2 miles east of Telluride, Colorado, at an altitude of 9,060 feet. The Treasury tunnel intersects the Black Bear vein 8,670 feet from the portal, and the Mill Level tunnel intersects the Argentine vein 7,150 feet from the portal. Mining is by shrinkage stoping from slusher sublevels. The size of the stope blocks varies somewhat, but the standard size is 220-250 feet long and 200-250 feet high. The mine ranks either first or second in Colorado in yearly production of gold, silver, copper, lead, and zinc.

It is 6 miles from the Red Mountain plant to the Pandora plant, via interconnecting drifts and raises. There are engineering offices at both plants as a matter of convenience. The Red Mountain plant includes the company general offices, warehouse, carpenter and machine shops, and mine change-room. The Pandora plant consists of the mill and assay office, machine shops, and mine change-room. The flotation mill has a capacity of 1,800 tons per day, making a bullion product and separate concentrates of lead, copper, and zinc.

HISTORY OF THE MINE

The Montana-Argentine vein was first extensively worked by the Tomboy Gold Mines Co., Ltd., a British concern. This company mined the stoped areas above the Ophir level between 1910 and the late 1920's and most of the stoped areas above the 2,100 level between 1900 and the late 1920's. Gold was the principal ore metal mined.

The area between the Revenue and Ophir levels was mined chiefly by the Revenue Mines Co. between 1900 and 1910. The ore was worked from the Revenue tunnel, which portals in Canyon Creek. Gold and silver were the chief metals recovered.

The stopes between the 1,700 and Revenue levels, as well as some higher stopes, were mined by Telluride Mines Inc. during the 1940's. The Mill Level tunnel was driven by that company in 1945-1948. Lead and zinc then became economically more important than the precious metals. In 1953, Idarado purchased Telluride Mines, which was merged with the parent company in 1956.

The Black Bear vein was first extensively worked by the Black Bear Mining Co. in the 1900's and by the Colorado Superior Mining Co. from about 1914 until snowslides at the mine camp (altitude 12,300 feet) terminated the company's operations in 1924. Leasers operated at intervals until 1934. The Treasury tunnel, formerly the Hammond tunnel, had been started before 1900 and reached the 5,400-foot mark early in the 1900's, at which time activity lagged until the late 1930's. In the early 1940's, Idarado extended the Treasury tunnel (from its heading at 5,400 feet) to the Black Bear vein and established a raise connection with the 600 level, the lowest level in the old mine.

Since completion of initial work in the mid-1940's, systematic development of the mine, both in the driving of new headings and the utilization of older openings, has resulted in the present extensive network of workings.

ACKNOWLEDGMENTS

The writer wishes to express his sincerest appreciation to John S. Wise, General Manager, the Idarado Mining Company, for permission to publish this description and for reviewing the manuscript from his knowledge and familiarity with the Black Bear and Argentine veins. I wish also to thank W. B. Paris, Telluride, Colorado, for the rock and sphalerite assays quoted herein.

DESCRIPTION OF VEINS

The Black Bear and Argentine veins range from 2 to 25 feet in width, but in most places are 5-7 feet wide. They vary in character from a well-defined tabular structure between sharp "frozen" walls, or gouge seams, to an irregular zone of quartz and quartz-sulfide stringers. Many gouge seams within the veins make the veins blocky and loose.

Vugs, in most instances lined with quartz crystals, are common throughout the veins and range in size from spheroids 3-6 inches in diameter to ellipsoids 25 x 10 x 5 feet. The larger cross-section more or less parallels the vein. However, the vugs transect the vein, and in places extend into the vein walls, suggesting they resulted, in part at least, from solution of the vein and wallrock.

Common gangue minerals in the veins include quartz, pyrite, rhodonite, chlorite, sericite, clay minerals, epidote, calcite, adularia, rhodocrosite, fluorite, and specularite. Quartz constitutes 60-70 percent of the veins and varies widely in character, ranging in color from clear through

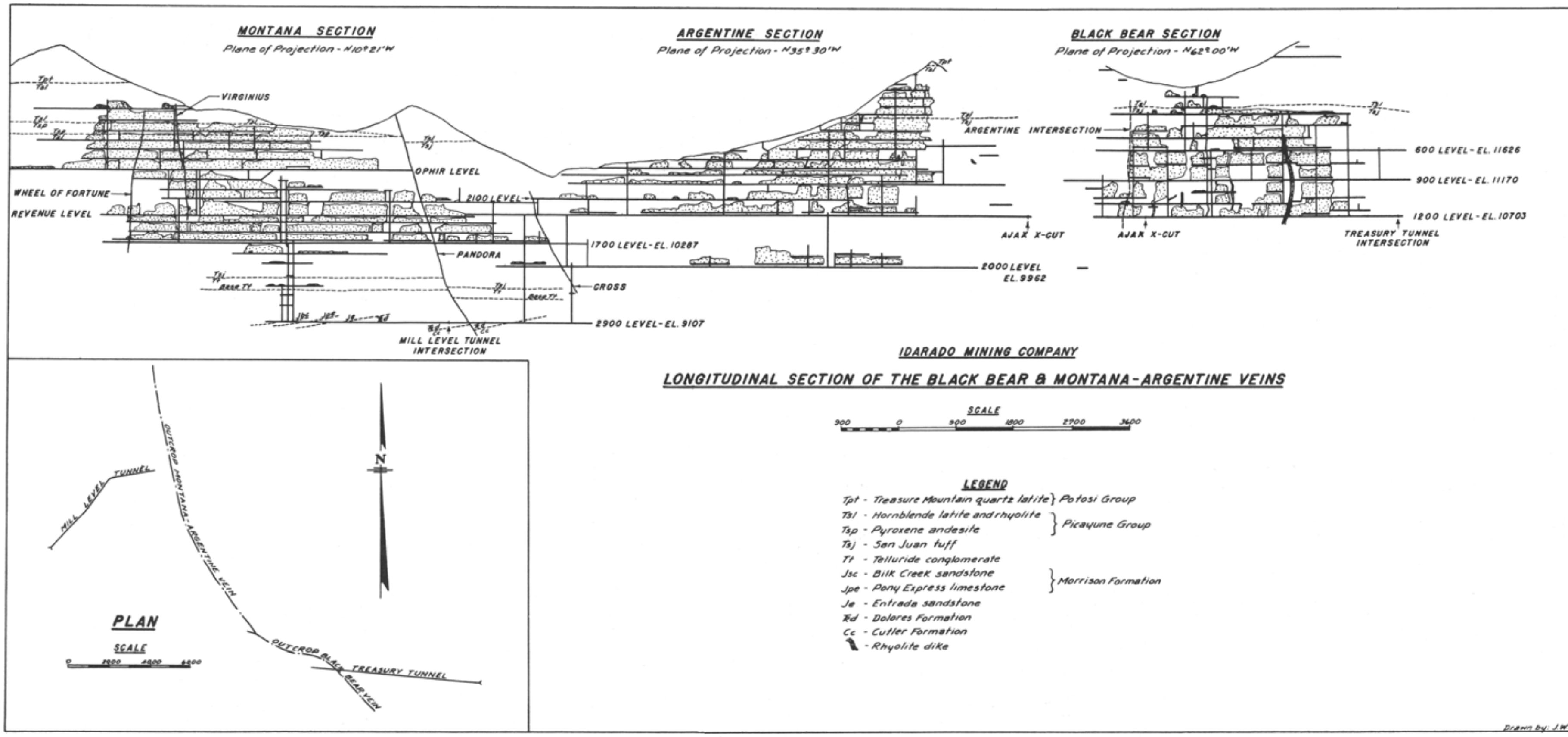

MONTANA SECTION
Plane of Projection - N10° 21'W
ARGENTINE SECTION
Plane of Projection - N35° 30'W
BLACK BEAR SECTION
Plane of Projection - N62° 00'W
VIRGINIUS
OPHIR LEVEL
WHEEL OF FORTUNE
REVENUE LEVEL
2100 LEVEL
1700 LEVEL - EL. 10287
PANDORA
CROSS
2900 LEVEL - EL. 9107
MILL LEVEL TUNNEL INTERSECTION
2000 LEVEL EL. 9962
ARGENTINE INTERSECTION
AJAX X-CUT
600 LEVEL - EL. 11626
900 LEVEL - EL. 11170
1200 LEVEL - EL. 10703
TREASURY TUNNEL INTERSECTION
IDARADO MINING COMPANY
LONGITUDINAL SECTION OF THE BLACK BEAR & MONTANA-ARGENTINE VEINS
SCALE
900 0 900 1800 2700 3600
LEGEND
Tpt - Treasure Mountain quartz latite } Potosi Group
Tsl - Hornblende latite and rhyolite
Tsp - Pyroxene andesite } Picayune Group
Tsj - San Juan tuff
Tt - Telluride conglomerate
Jsc - Bilk Creek sandstone
Jpe - Pony Express limestone } Morrison Formation
Je - Entrada sandstone
T̄d - Dolores Formation
Cc - Cutler Formation
- Rhyolite dike
PLAN
SCALE
0 2000 4000 6000
MILL LEVEL TUNNEL
OUTCROP MONTANA - ARGENTINE VEIN
OUTCROP BLACK BEAR VEIN
TREASURY TUNNEL
N
Drawn by: J.W.S.

Figure 1.

white, gray, and green, to amethyst, in luster from viterous to "oily" and porcellaneous, and in crystallinity from chalcedonic, through very fine-grained "bony", to large zoned crystals 10 inches long and 5 inches in diameter. Much of the quartz shows banding or crustification, with layers of various quartz types, adularia, rhodonite, and fine-grained sulfides. Chlorite, sericite, the clay minerals, and fine-grained quartz are common alteration products of the vein walls and of wallrock fragments in the veins. Epidote is an alteration of the dike, or less commonly, of tuff-breccia. Calcite, adularia, fluorite, and rhodocrosite, which are widespread but not abundant, form vein fillings with banded or crustified late-stage quartz. Rhodonite is more abundant and occurs either replacing country rock or as a vein filling. Pyrite is moderately abundant, occurring as disseminated 0.1-inch cubes in the vein walls and as scattered granular masses or crystals in the veins. Specularite occurs in small quantities in scattered areas.

The major ore minerals are sphalerite, galena, chalcopyrite, and native gold. The sulfides, which occur in grains 0.06-0.5 inch in diameter, may show crystal faces, but euhedral crystals are limited to tiny crystals in vugs. The sulfides occur in separate bands or streaks in the veins, although in juxtaposition with bands or intergrowths of the other sulfides. This is particularly true of chalcopyrite. Intergrowths of sulfides usually involve any two sulfides, less commonly all three. The overall ratio of Zn: Pb: Cu for the veins is about 3: 2: 1.

Native gold occurs as thin plates around quartz crystals or sulfide grains, and rarely as wire or in crystals. The gold is usually finely disseminated and not readily visible to the unaided eye. The gold has a wide range of fineness, and ranges in color from pale yellow to almost a copper red.

The vein filling varies considerably in detail. One 15-foot section of the vein can show radical changes with adjacent sections as to structure, character and amount of gangue and ore minerals present, and the texture of ore. Every conceivable combination of mineralogy, structure, and ore texture described in this report can be found in the veins.

Alteration of wallrock, or of wallrock septa within the veins, is common but variable. In places the walls are of relatively fresh rock, but elsewhere they may show extensive "bleaching" for distances of 3-10 feet from the vein. Alteration nearest the vein is to quartz-sericite, with local argillization. Outward from the vein the alteration is propylitic, with development of chlorite and related minerals in the groundmass of the dike or in the matrix or groundmass of included fragments in tuff-breccias. In the dikes replacement of feldspar phenocrysts by chlorite or rhodonite has been observed. Minor epidotization occurs throughout the veins, but it is notably intense along the south Argentine 2,000 level.

STRUCTURE OF THE MONTANA-ARGENTINE VEIN

The southern half of the Montana-Argentine vein strikes N. 35° W. and the northern half N. 10° W. The overall dip is about 70° west but in detail may depart markedly from this attitude. The vein lies along a fault zone that closely follows a premineralization andesite dike. The dike is 3-20 feet wide and in many areas is complex, pinching out, forming two or more segments enclosing large horses of country rock, or fingering irregularly into the country rock (Fig. 2).

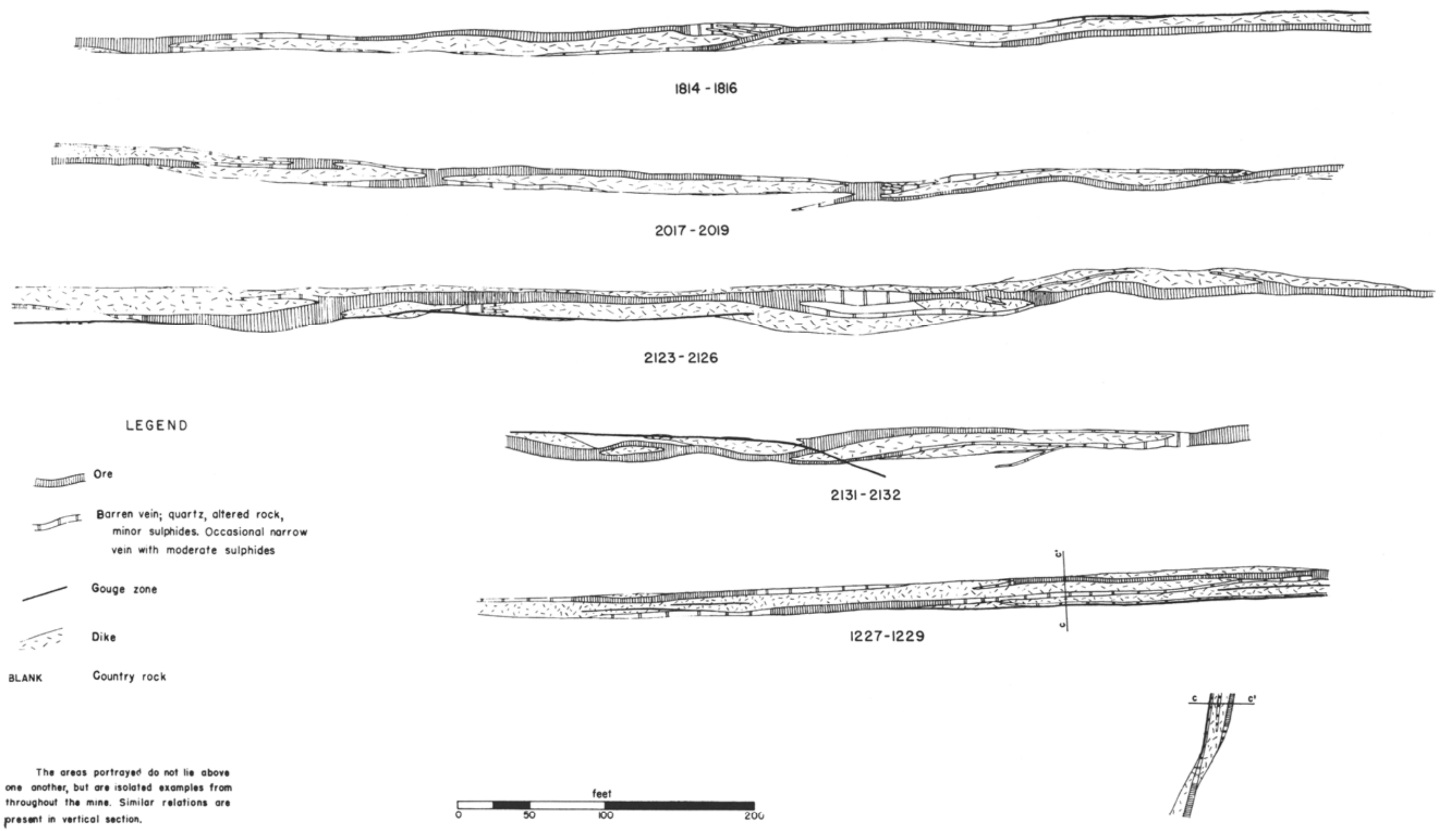
The vein, which has been traced for 16,000 feet, is terminated at the north by the northwest-striking Terrible vein and at the south by the Black Bear vein. The dike persists further south but is offset horizontally 10-15 feet to the west in the hanging wall of the Black Bear vein. However, mineralization is limited to sporadic gouge slips or narrow quartz stringers on the walls of the dike.

The Montana-Argentine vein is cut and offset by several other veins. According to old level maps, the Montana-Argentine vein is offset about 10 feet to the west on the north side of its intersection with the northeast Wheel of Fortune vein, and it is offset 30 feet to the west on the south side of its intersection with the northwest Virginius vein. The Montana-Argentine vein is offset about 30 feet to the west on the south side of its intersection with the Cross vein. The character of the latter offset is variable. On the 1,700 level it is a well-defined break. On the 1,200 level the offset occurs along a wide zone of small parallel slips and quartz stringers. The movement along any one of the slips did not displace the Montana-Argentine vein more than a few inches, giving an overall appearance of a gradual warp of the vein. The Pandora-Camp Bird vein effects the greatest displacement, as the section of the Montana-Argentine vein south of the intersection is offset 60-70 feet to the west.

The andesite dike exerted a strong influence on the detailed localization of ore. The vein may occur in one or more of three positions (fig. 2) : (1) footwall of the dike, (2) hanging wall of the dike, or (3) within the dike. A single pay streak is usually present in one of the three positions, with minor veins or gouge slips in one or both of the other two positions. The pay streak may switch from one position to another within short distances. Beyond the limits of a pay streak, the vein in some instances consists of 4-6 feet of vuggy coarse white quartz or quartz stringers in dike rock cut by gouge slips, and in other instances the vein may narrow to a quartz or gouge streak 1 inch wide. In general, the margins of the pay streaks are marked by a decrease in vein width to 1 or 2 feet, a decrease in sulfide content and to a lesser degree of quartz, an increase in altered rock in the vein, and the presence of numerous gouge slips.

"Rolls," local changes in dip, are common along the vein. They consist of a flattening or steepening of the vein walls either singly, together in unison, or together in opposition, and may therefore cause a swelling, pinching, or no change in the vein width. A common type is a flattening of the vein footwall and a 3-4-foot increase in vein width. The rolls average 10-30 feet high and 25-30 feet long, although some are much longer. Similar, though less common, pinches and swells result from changes in strike of the vein walls.

Much of the Montana-Argentine vein shows lode characteristics. In such areas the vein consists of a 5-12-foot-wide zone of quartz stringers, bands of silicified rock, and quartz-sulfide stringers in dike rock. The stringers are 2-8 inches wide and generally have "frozen" walls. One or



SCHEMATIC PLAN MAPS ILLUSTRATING TYPICAL DIKE-VEIN RELATIONS ON THE ARGENTINE VEIN

Figure 2.

both walls of the zone may have a smooth surface or gouge zone. In most areas the stringers comprise 30-40 percent of the lode zone, although there are all transitions between a massive quartz-sulfide vein and two or three stringers in country rock. Usually only the part of the lode that contains quartz-sulfide or sulfide stringers is economic, and the remainder is barren quartz stringers. The economic part is nowhere well-defined and wanders irregularly in the lode.

Longitudinal faults cross the vein at low angles, varying from the vein attitude by only 3°-8°. Zones of gouge 1-6 inches wide mark the fault planes and offsets are only 1-5 feet. The faulted portions of the veins are seldom completely separated.

Sheeting (zones of sharp fractures 4-12 inches apart) occurs both in the country rock and in the dike, lying parallel to the vein and/or the dike walls. Sheeting is more common and more strongly developed at depth and to the north.

Except for the junction with the Black Bear vein near the 1,200 level, the Montana-Argentine vein's structural character is consistent throughout the developed length of 15,000 feet and depth of 3,500 feet. The vein extends downward from the Picayune group, through the San Juan tuff and Telluride conglomerate, into the underlying pre-Tertiary sediments (Fig. 1) .

STRUCTURE OF THE BLACK BEAR VEIN

In general the Black Bear vein strikes N. 45° W. in its east half and N. 63° W. in its west half (Fig. 1, Plan) and dips about 60°. However, there are marked local variations from this attitude. To date only the west half has been explored. Work on the southeast segment is limited to the last few hundred feet of the east 900 and 1,200 levels (Fig. 3).

The limits of the vein have been defined only on the west, and here but approximately. The west margin is marked by the gradual fade-out of the controlling fault and a decline in mineralization along it. The margin rakes southeast, for vein structure is present at the west face of the 900 and 1,200 levels but only a wide zone of curved sheeting is present below these points on the 2,000 level (Fig. 3).

The vein fingers updip and splitting commences in the vicinity of the San Juan-Picayune contact. The splits, at least three in number with connecting diagonals, are characterized by intense alteration and little quartz or sulfide. In consequence the outcrop of the Black Bear vein consists of a discontinuous vein with no direct indication that mineralization is of ore grade.

The vein is not offset by any cross structures within the explored length of 5,400 feet. Except for the areas mentioned above and sections of the Argentine junction, the vein is quite uniform throughout. Sheeting and rolls similar to those described for the Argentine vein are present, although sheeting is less common in the Black Bear vein. A few longitudinal faults are present. Some areas have lode characteristics, but in general the vein is well-defined with quartz predominant.

BLACK BEAR-ARGENTINE JUNCTION

The junction of the Black Bear and Argentine veins between the 900 and 2,000 levels is shown in Figure 3. The simple junction which persists down to the 900 level breaks up into a series of cymoid loops between the 900 and 1,100 levels, and at the 1,200 level the loops fail completely to close. Although the pattern on the 2,000 level is poorly known, the Black Bear structure does not persist as far west as it does on the upper levels, and the Argentine dike and vein, which are separated for 2,500 feet north of the junction of the 1,200 level, are together on the 2,000 level.

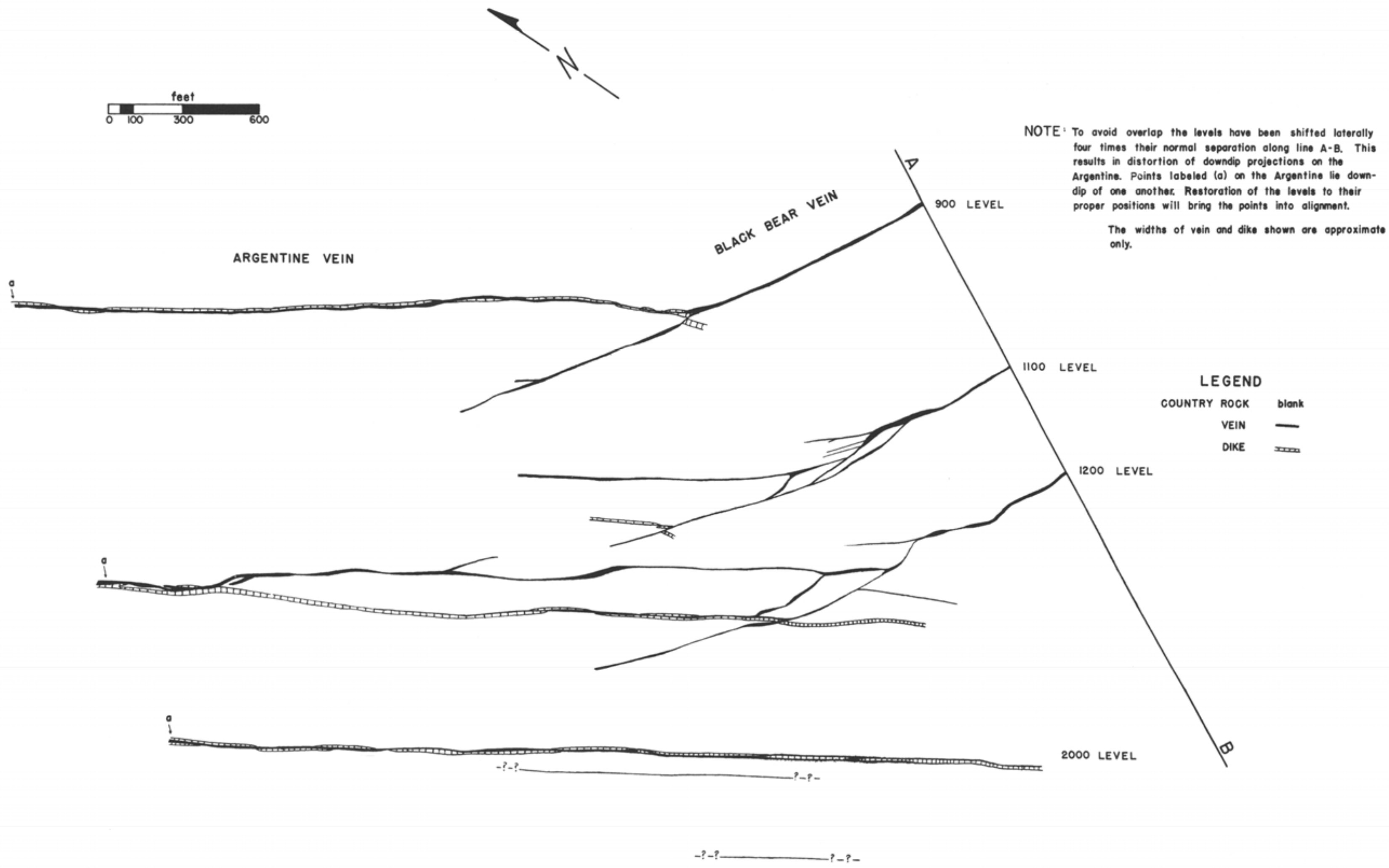
CHARACTER OF THE VEIN-FAULT MOVEMENT

The Black Bear and Argentine veins lie along zones of normal fault movement. Although some movement on the fault occurred prior to and during mineralization, most of the movement has been after mineralization. The planes of movement are marked by zones of gouge and sheared rock from an inch to two feet wide. Mullion structure on the walls indicates the movement has been predominantly dip slip on the Argentine vein. Along the Black Bear vein there has been a large component of strike slip.

An interesting feature of the faulting is the nonuniformity of the movement along the zone. For example, where the Black Bear vein cuts the rhyolite dike on the 900 level it consists of a pronounced gouge zone 6-12 inches wide which offsets the dike 12 feet. On the 1,200 level, several small slips, but no large or continuous ones, are present, and the dike is not offset by the vein. Along both the Black Bear and Argentine veins are numerous examples of postmineralization cross fractures that are offset 3-10 feet by gouge slips in or on the walls of the vein. These slips may cross from one wall of the vein to another and in the process they "stretch" the vein, leaving a barren gap equal to the lateral displacement. The notable feature is that at some point the slips fade out and the vein possesses "frozen" walls with no internal planes of movement. Here no post-mineralization movement took place, structural adjustment occurring in jointing or sheeting of the country rock away from the vein. A few hundred feet farther on, gouge slips showing differential movement reappear. The net slip ranges from zero to a probable maximum of 40 feet on the Black Bear (determined from offset of the Argentine dike on the 1,100 level) and 15 feet on the Montana-Argentine (determined from offset of the Pony Express limestone), the amount varying irregularly along the structures.

PARAGENESIS

Minerals were deposited in four main stages: (1) base-metal sulfides; (2) quartz, with veining and brecciation of the earlier sulfides; (3) base-metal sulfides in interstices of quartz crystals; and (4) gold. Of the other common vein minerals listed, chlorite, sericite, the clay minerals, and most of the pyrite are the products of wallrock alteration and therefore belong to stages 1 and 2. Adularia, fluorite, rhodocrosite, and some rhodonite are associated with the



GEOLOGY OF THE BLACK BEAR-ARGENTINE VEIN JUNCTION

Figure 3.

late substages of quartz deposition when crustification was common; they therefore belong to stage 2 (late) through stage 4. Calcite is associated with very late quartz (stages 3 and 4) and in part is the youngest mineral deposited. Epidote and most of the rhodonite are presulfide and belong to stage 1. The position of specularite in the sequence has not been determined. In some instances it is intermixed with the sulfides, but more commonly it occurs isolated in coarse white quartz. Varnes (1947) placed it late in the sequence.

STAGE 1

The first stage accounted for most if not all of the base-metal sulfides, some quartz, and an unknown amount of wallrock alteration. The sulfides were deposited primarily as a replacement of country rock, and to a far lesser degree as filling of open cavities formed by differential movement of the vein walls or by presulfide solution of wallrock along the vein. Along the Montana-Argentine vein the andesite dike was altered or replaced in preference to the San Juan tuff. Some alteration and quartz preceded or accompanied the sulfides. The amount of quartz in stage 1 was small, particularly compared to the quartz of the second stage; some alteration occurred during both stages 1 and 2, but the relative amounts are in doubt. If, as seems possible, the silica of the quartz of stage 2 was released through alteration of the wallrock, most of the alteration would belong to the second stage.

The sulfides were all introduced at the same time. Extensive megascopic and limited microscopic work reveals no consistent sequence among the sulfides. Most often, sphalerite is earliest, followed by chalcopyrite-galena or galena-chalcopyrite, but reversals and repetitions are common enough to minimize the apparent sequence. Rather than sequence of introduction, the sulfide paragenesis is believed to represent relative stability (or mobility) of the minerals in a system of declining energy which varied throughout the vein. At the close of stage 1 the veins consisted of narrow lenses of massive or near-massive sulfide and minor quartz, with walls of unaltered to moderately altered country rock.

STAGE 2

The second stage involved the introduction of quartz of the types previously described. Probably 75 percent of the vein quartz belongs to this period. Its substages are incredibly numerous and involved, and correlation between them virtually impossible. Comparison of age relations of two substages in areas 50-100 feet apart may show either or both present in one area and absent in the other; their relative ages reversed in the two areas; or their occurrence in immediate sequence in the one area while separated by one to four separate substages in the other.

The most important feature of the quartz introduction was the concomitant redistribution of the earlier sulfides. There is a complete sequence of relationships: (1) original massive sulfide; (2) sulfide with a few quartz stringers; (3) sulfide cut by a coarse network of stringers, commonly forming a quartz-cemented breccia of sulfide and wallrock fragments 1/2-1 inch in diameter; (4) quartz containing closely scattered sulfide blebs; (5) quartz containing widely scattered sulfide blebs; and (6) barren quartz. Textures of relationships 2, 3, and 4 (exclusive of well-developed breccia) are the most common in the vein, although locally the others, particularly barren quartz, are abundant.

A series of analyses of altered wallrock marginal to the vein was made to determine if the silica of the vein quartz could have been released from the wallrock during alteration. The results are shown in Table 1.

TABLE 1

Analyses of wallrock, Black Bear vein, 606 Block*

	1.	2.	3.	4.	5.	6.
$CaCO_3$†	5.30	5.10	1.55	1.55	3.50	2.95
Soluble #	13.60	5.30	14.20	17.50	16.65	15.60
SiO_2	50.90	54.35	62.75	57.10	55.65	58.30
Al_2O_3	21.20	20.60	17.55	19.05	20.35	19.05
Fe_2O_3	6.65	6.60	1.20	1.50	1.15	1.55
CaO	0.70	6.15	1.05	0.80	0.30	0.95
MgO	0.90	0.55	0.30	0.85	0.65	1.20
Na	spectroscope shows very small amounts					
K	spectroscope shows very small amounts					
	98.95%	98.65%	98.60%	98.35%	98.25%	99.60%

* Wm. B. Paris, Telluride, Colorado, analyst.

† $CaCO_3$ soluble in dilute acetic acid.

Other material soluble in dilute oxidizing acid. Chiefly pyrite.

1. Ten feet in vein footwall. Green tuff-breccia with red andesite fragments; considerable pyrite.
2. Ten feet in vein footwall. Slightly bleached green tuff-breccia with red andesite fragments; little pyrite.
3. Four feet in vein hanging wall. Bleached white and pink, latter areas marking andesite fragments; considerable pyrite.
4. Two feet in vein hanging wall. Bleached white; considerable pyrite.
5. One foot in vein footwall. Bleached pale green and pink; considerable pyrite.
6. Horse in vein. Bleached white and pink; considerable pyrite; small quartz blebs and veinlets.

Although the altered rock has a higher percentage of silica, the density of the rock decreases on alteration; unaltered San Juan tuff averages about 2.65 in density, but altered rock ranges from 2.1 to 2.6 and averages about 2.4. Therefore, the altered rock probably contains no more silica per unit volume than the unaltered rock. Because of the wide range in density and variable development of the altered rock, the amount of silica released into the vein cannot be estimated. The lack of any quantitative relation between the amounts of quartz in the vein and the alteration of the adjacent walls indicates that the silica, if released through wallrock alteration, migrated distances as much as several hundred feet along the vein before deposition.

Some of the quartz of stage 2 is a replacement of country rock, as indicated by altered and silicified wallrock pseudomorphs in the vein. However, the sharp-walled character of the majority of quartz veinlets and the abundance of vugs of all sizes strongly suggest that most of the quartz filled open spaces, probably more or less concurrent with their formation. Two origins of the openings are evident; (1) solution of wallrock and earlier vein material, and (2) dilation along the vein fault zone. The relative importance of each is uncertain.

STAGE 3

Stage 3 consists of: (1) deposition of sulfides between the crystals and along the crystal boundaries of stage 2 quartz, and (2) continued deposition of quartz, particularly the finer-grained and chalcedonic varieties. The quartz crystals of stage 2 that are involved in stage 3 range from several inches long and an inch in diameter to I/8 inch long and corresponding diameter. The texture of sulfides interstitial to quartz is fairly common, though not abundant compared to that resulting from introduction of quartz in stage 2. The sulfides are believed to represent redeposition of material mobilized during stage 2 rather than introduction of new material. Chalcopyrite is the most common sulfide in the interstitial texture, indicating a greater mobility of that mineral under the existing conditions.

STAGE 4

Stage 4 is the introduction of native gold, which occurs in quartz that ranges from coarse white material to crustified types in which "bony" white, fine-grained greenish, and medium- to coarse-grained amethystine varieties are prominent. Most of the quartz belongs to stages 2 and 3 but some may represent stage 4. Fine-grained sulfides, usually chalcopyrite and light-colored sphalerite, accompany the gold. These probably represent redistributed sulfides.

A strong physical-chemical discontinuity occurred in the mineralization process between stages 1 and 2. That between stages 2 and 3 is not marked, apparently representing a point in the gradual decline of stage 2 activity. The change from stage 3 to stage 4 is marked entirely by the start of gold deposition.

ZONING

Although the Black Bear and Montana-Argentine veins acted largely as two units structurally, they comprise but one unit mineralogically, and a well-developed zonal sequence extends laterally outward from the Black Bear and along the Argentine. To a considerably lesser degree, a similar pattern exists in vertical section.

Metal distribution can be summed up in the following rules:

(1) The total base-metal content decreases to the north.

(2) Copper increases to the south and at depth, both in quantity and relative to the total base metals.

(3) Zinc decreases to the north and at depth in quantity and, to a lesser degree, relative to total base metals. To the south and at depth it decreases relative to copper but increases relative to lead.

(4) Lead decreases in quantity at depth and north and east of the south Argentine-west Black Bear area. It increases relative to the total base metals updip and to the north.

(5) Gold decreases at depth and south of the Pandora vein.

(6) Silver increases at depth and to the southeast, except for a belt of high silver values in the Montana section between the Virginius and Wheel of Fortune intersections.

The following paragraphs describe in greater detail the distribution pattern of each metal and several gangue minerals.

GOLD

Throughout the vein system gold shows a systematic decrease downward. On the Black Bear, the overall gold values decline 45 percent between the 600 and 1,200 levels. Gold is also more abundant at the east end of the vein. In the Argentine area, the old stopes above approximately 11,600 feet altitude were characterized by very high gold values—from one-third to several ounces per ton. At lower elevation the gold values decline markedly, being one-tenth or less those at the higher horizons—the lowest on the vein system. In the Montana section, high gold values were also present at the higher elevations, decreasing in depth. Excluding the gold shoots in the upper Montana and Argentine sections, for which complete assays are unknown, gold values in the area north of the Pandora vein are consistently 2-4 times those of the area south of the vein.

SILVER

With one exception silver values increase downward and to the south. On the Black Bear, overall silver values increase 50 percent between the 600 and 1,200 levels. Silver is most abundant at the east end of the vein. On the Montana-Argentine, silver values at the south end of the vein and at depth are 2-3 times those to the north, although slightly less than those on the Black Bear 1,200 level.

The exception is an area of high silver values in the Montana section between the Wheel of Fortune and Virginius intersections. The latter veins, the Virginius in particular, are noted for their sliver production. Silver values in this area are 4-8 times those of areas outside the shoot. Values are still a fraction of the reputed 45 ounces and over of much of the Virginius ore.

Although most of the silver is recovered in the lead concentrate, suggesting a mineralogical association with galena, metal distribution maps indicate the silver content of the ore is closely related to that of copper. Individual areas may depart from this relation but overall it holds rather closely.

LEAD

Lead content of the ore increases relative to the other metals at higher elevations and to the north. Northward along the vein system lead shows the smallest quantitative decline of any base metal.

On the Black Bear, lead shows only a slight decline between the 600 and 1,200 levels. However, it does show a marked increase, both in quantity and relative to the other metals, in the west half of the vein. At the east end the ratio of Pb: Zn is 1: 2 but at the west end it is between 1: 1.5 and 1: 1. In the Argentine area above 1,200 level, the Pb: Zn ratio also is between 1: 1.5 and 1: 1. However, lead shows a marked decrease at depth, both quantitatively and relative to the total base metal. Values on the 2,000 level are 30-50 percent less than those on the 1,200 level and above. In the Montana area, the Pb: Zn ratio varies from 1: 1 at the south end to 2: 1 at the north end. The lead values are 60-90 percent of those elsewhere on the vein.

ZINC

Zinc decreases in quantity, and to a lesser degree relative to total base metals, at depth and to the north. The latter areal relation is more pronounced, as the Pb: Zn ratios discussed above would indicate.

On the Black Bear, zinc decreases 15 percent between the 600 and 1,200 levels. Highest zinc values are present in the east end of the vein. In the Argentine section, zinc values decrease about 10 percent between the 2,100 and 2,000 levels. Because the increase in copper is compensated by a decrease in lead, the Zn: tbm (total base metal) ratio shows a decrease of less than 10 percent, and locally a slight increase. The quantitative decline continues northward into the Montana section, where valeus are one-third to one-half those to the east. Here also the Zn: tbm ratio shows a smaller decline, the decrease in zinc being partially offset by a marked decrease in copper.

COPPER

Copper increases at depth and to the south and east. On the Black Bear, copper shows an increase of 30 percent between the 600 and 1,200 levels. It is most abundant at the east end of the vein. In the Argentine section, copper values increase 25-50 percent between the 2,100 and 2,000 levels. The best copper values yet encountered are in this area on the 2,000 level. Northward copper decreases rapidly. North of the Pandora vein, copper is absent or is present in amounts varying from a trace to 0.1 percent, 10-20 times less than the content in the Argentine area.

TUNGSTEN

Tungsten in the form of hubnerite and wolframite, is reported from the north Montana on the 1,700 level. It has not been identified elsewhere.

RHODONITE

Updip and northward along the vein system rhodonite becomes a common, and in places abundant, gangue mineral. Areas of abundant rhodonite are usually associated with high lead values. Rhodonite is erratic in distribution, and even in areas where generally baundant, rhodonite may be absent for vein lengths of 300 or more feet. On the Black Bear, rhodonite is more common on the upper levels, but is nowhere abundant. On the Montana-Argentine, rhodonite is common to abundant above a line from the north face of the 2,000 level through a point 550 feet from the Black Bear junction on the 500 level; below this line it is generally absent. Rhodonite distribution in the north Montana is unknown.

EPIDOTE

Epidote is common to abundant at the south end of the Argentine 2,000 level. It is widely present, but not abundant, at higher elevations in the Argentine section and on the Black Bear. Epidote shows a strong preference for forming as an alteration of dike rock, and its less common occurrence on the Black Bear may be related to this factor.

TEMPERATURE OF ORE FORMATION

A series of temperature determinations, based on the iron content of sphalerite (Kullerud, 1953), was made along the Black Bear and Montana-Argentine veins. Twenty-four sphalerite samples of paragenetic stage 1 were collected from selected areas of the vein system. The samples all contained considerable pyrite, which was removed before analysis. A pressure correction based on the maximum possible hydrostatic head at the specific depth was employed. The results may be summarized as follows:

(1) The highest FeS content was 3.4 percent, the lowest 0.6 percent, and the average and mean value 2.2 percent. These values are all within the extrapolated range of Kullerud's graph lying below 140° C.

(2) The samples show no systematic variation along the vein or with depth. High and low iron contents are present at all elevations and distances northward along the vein.

(3) In consequence of (2), temperature shows no relation to areas of better grade mineralization or to the zonal pattern. Therefore, either the zonation does not reflect temperature, or the FeS content reflects equilibrium conditions attained subsequent to deposition under the zonal pattern. The latter alternative requires recrystallization of the sphalerite in a system of declining energy, and fixation under temperature conditions that were generally homogeneous but locally quite variable. Although such recrystallization took place (paragenetic stages 3 and 4), the writer questions whether the assumption that zonation is primarily a result of temperature gradient is justified here and elsewhere.

ORE DISTRIBUTION

ORE SHOOTS

In the developed area of the Black Bear vein, ore shoots (relatively large area of total or predominant ore versus areas of total or predominant waste) are not present within the San Juan tuff. Waste areas exist only as isolated blocks of irregular outline, which in many cases possess a long axis oriented vertically, or less often, horizontally. The vein has a very high payability, on the order of 80-90 percent.

By the same definition ore shoots are absent on the Montana-Argentine vein within the volcanic rocks. However, shoots of better grade and more persistent mineralization are present in the vein. Three such shoots are present: (1) the Argentine shoots near the south end of the vein, having a strike length of about 3,500 feet; (2) the Cross shoot near the Cross vein, having a strike length of 2,000-3,000 feet; and (3) the Montana shoot in the area of the Virginius and Wheel of Fortune intersections, having an indicated length of 800-1,000 feet below the 1,700 level, but probably greatly in excess of this in the stoped areas above. The Argentine shoot is the richest and best defined. Between the shoots, ore and waste occur in erratically distributed blocks several hundred feet on a side, and the proportion of waste blocks to ore increases northward along the vein. The vein has a high payability, on the order of 65-70 percent.

The size of the Idarado stope blocks should be remembered in considering these statements. These blocks range from 150 to 250 feet in length and 100 to 250 feet in height. Waste areas are those which are any multiple or major fraction of the stope block dimensions and which average under the minimum grade. Blocks of waste may include ore-grade mineralization in areas as much as 50 feet on a side. Similarly, each block of ore includes stretches of non-ore mineralization for lengths of 25 and sometimes even 100 feet, but the total of such areas is insufficient to bring the average for the block below the minimum grade.

RELATION TO LITHOLOGY

In the Black Bear vein ore is largely restricted to the San Juan tuff, but the vein has not been explored to any extent outside this formation. As previously noted, the vein fingers upward, the splitting commencing near the San Juan-Picayune contact. This feature, which may be related to depth of burial and/or to different structural response in the two formations, accounts more for the reduced favorability to be expected in the Picayune than does any chemical feature of the formation. The Picayune exposed on the 100 level is little different lithologically from the tuff below.

The rhyolite dike is unfavorable. Excellent ore may occur on either side of the dike, whereas the vein within the dike is marked by a narrow zone of sheared rock or by a broken zone of quartz stringers with minor sulfides.

In the Argentine vein ore persists through the San Juan tuff and Picayune group. The Potosi group has not been extensively explored, but throughout the district the formation is unfavorable, the veins tending to split and fade out in crackled rock in a manner similar to the Black Bear vein where it intersects the rhyolite dike. Ore has been found in the top part of the Telluride conglomerate. It is absent everywhere within the pre-Tertiary sediments, including redbeds of the Cutler and Dolores formations, the Entrada sandstone, the Pony Express limestone, and the Bilk Creek sandstone. In these rocks the vein is narrow and consists of quartz and gouge. Bleaching of the redbeds (siltstone, arkose, and shale) is negligible and nowhere extends more than a few feet from the vein. In the Pony Express limestone the vein consists of gouge slips 4 inches to 2 feet wide on either side of the dike. The limestone is unaffected by mineralization. The black fine-grained lower unit extends within inches of the vein without bleaching or recrystallization.

RELATION TO STRUCTURE

Three features can be considered under this heading: (1) relation of ore to members of the premineral fault zone; (2) relation of ore to variations in strike and/or dip of the vein, and (3) relation of ore to vein intersections and junctions.

Premineralization faulting unquestionably controlled the pattern of sulfide mineralization, and in local areas a relationship is still discernible between intensity of sulfide mineralization and the strength, number, pattern, and character of the premineral breaks. However, subsequent events, particularly the quartz mineralization of paragenetic stage 2, so disrupted the earlier pattern that that it is now apparent only on a very small or very large scale.

Locally the vein contains pods of strong mineralization or barren areas related to abrupt changes in the strike or dip of the vein. These generally have dimensions of 15-100 feet and are individually of little significance. A half-dozen may be encountered in a single stope block. The relation of mineralization to vein attitude is not consistent, and a particular change in attitude associated locally with an increase in mineralization may elsewhere show a decrease or no change. Attempts to obtain a pattern between attitude variations and areas of stope-block dimensions were not successful, for three reasons. First, as already mentioned, a stope block will include numerous minor attitude variations which can control ore locally, but because of their small size they are not discernible until the stope itself is mined. Second, attitude variations reflect premineralization and postmineralization faulting and fracturing but do not provide a measure of the important redistribution effected in paragenetic stage 2. Third, the value of the ore depends on five metals, and a notable amount of one may compensate for a deficiency of several others.

Ore is not localized at the Argentine-Black Bear junction, nor at the intersection of the Montana-Argentine with the other veins mentioned. The junction does not influence grade or widths of mineralization in the Black Bear. At all the intervals explored in the Argentine, waste or moderate-grade mineralization persists in narrower-than-average widths for several hundred feet north of the intersection. In the cymoid areas on the 1,100 and 1,200 levels, ore is absent from most of the branches because of narrow widths and/or the absence of metal. However, the junction of two branches, particularly at the east end of a loop, may be accompanied by moderate to substantial widths of high-grade ore.

The intersection of the Montana-Argentine with the Cross, Pandora, Wheel of Fortune, and Virginius veins, has not resulted in high-grade shoots on either vein or near the intersection. However, a broad control of mineralization in the Montana-Argentine vein has been exerted by the intersections, as shown by localization of the Cross shoot near the Cross vein, the higher gold content north of the Pandora vein, and the high silver value in the Virginius-Wheel of Fortune area.

RELATION TO PARAGENETIC SEQUENCE

The quartz introduced in stage 2 influenced ore distribution in two ways. First, it widened the vein structure although reducing the grade of material in the process. Second, it redistributed the sulfides, but whether the redistribution tended to make the metal content more or less uniform along the vein, and to what extent, is unknown. If tending toward uniformity, the process fell quite short of its objective in detail.

GEOLOGIC FACTORS IN MINING

Geologic factors affecting systematic mining fall into three categories: (1) ore distribution and control; (2) dislocation by faulting; (3) conditions leading to excessive dilution in the shrinkage stopes. Item (1) was discussed in the preceeding two sections.

The effect of offset by the intersecting veins is self-evident. For this reason the veins cause less trouble than the longitudinal faults. The faults cut across the vein at a low angle, and so the miners tend to regard them as the true vein wall, with which the faults actually or nearly coincide for a short distance. If followed, however, faults will lead the stope away from the vein into the country rock. Systematic probing of smooth vein walls eliminates this hazard.

In the Black Bear vein, dilution results from caving of walls that are strongly altered or ore cut by strong fractures paralleling the pay streak of the vein. Such areas are not abundant.

Dilution in the Montana-Argentine vein is a considerable problem. Some of the causes are:

(1) In areas where the vein shows lode character, the pay streak may be confined to a part of the lode, the remainder consisting of barren quartz. The pay streak can swing from one wall to the other or lie in the center of the lode. In such areas it is necessary to determine if the pay streak can be broken from the rest of the vein, or if not whether the vein will average ore grade for the width to which it will be necessary to mine.

(2) The existence of gouge slips along the dike walls, and of fracturing within the dike and country rock parallel the dike and vein, have been described. These features, coupled with the tendency of the pay streak to 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 pre vent 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.

REFERENCES CITED

Kullerud, G., 1953, The FeZnS system as a geologic thermometer: Norsk. Geol. Tidssk, v. 32, pp. 61-147.

Varnes, D. J., 1947, Recent developments on the Black Bear vein, San Miguel County, Colorado: Colo. Sci. Soc. Proc., v. 15, pp. 135-146.